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Geology of the

Attwood Lake Area

District of Thunder Bay

By

Henry Wallace

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GEOLOGICAL MAP

(back pocket)

Map 2436 (coloured)–Geology of the Attwood Lake Area, District of Thunder Bay. Scale 1:31 680 (1 inch to ½ mile).

ABSTRACT

The Attwood Lake area, comprises a 440 km^2 area, and is centred approximately 320 km north of Thunder Bay. The area was mapped in detail at a scale of 1:15 840 in 1976.

The map-area is underlain by Early Precambrian rocks which are covered extensively by thin Pleistocene morainic deposits. The oldest rocks present are metavolcanics which envelope a younger sequence of metasediments in the centre of the area. The metavolcanic sequence consists predominantly of mafic pillowed flows, but around the northwestern side of Attwood Lake and between Vertente Bay and Weese Lake, these flows are intermixed with a high proportion of felsic to intermediate pyroclastic rocks. Chemical metasediments occur on both sides of the conformable metavolcanic-metasedimentary interface. The lower part of the clastic sequence consists of polymictic conglomeratic units rich in metavolcanic clasts, but the rest is composed of garnet-, staurolite-, andalusite-, sillimanite-, and cordierite-bearing metamorphic rocks derived from a wacke-mudstone succession. All of the supracrustal rocks have been metamorphosed to a (cordierite-almandine) medium grade.

Along the western side of Weese Lake, the supracrustal sequence is intruded by a major anorthositic sill, but elsewhere, mafic intrusive rocks are minor and uncommon. Three batholiths composed of trondhjemitic to granodioritic rock are in contact with the supracrustal sequence to the northwest, west, south, and east of Attwood Lake. To the south of the lake, the metasedimentary sequence is gradational into a migmatitic zone rich in garnet-bearing pegmatoid to granitoid quartz monzonite. Diabase dikes which intrude the eastern batholith are believed to be Early Precambrian in age.

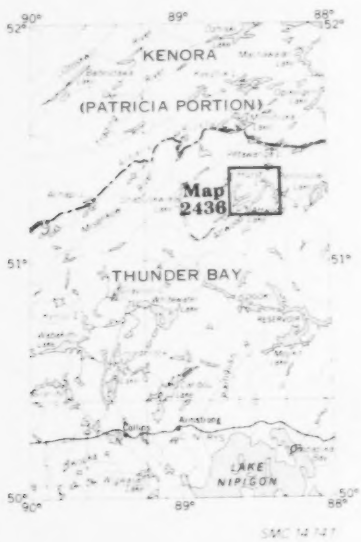

Figure 1–Key map showing location of the Attwood Lake Area.
Scale 1:3 168 000 (1 inch to 50 miles).

The distinctive rectangular lithologic pattern evident in this area is a fold interference pattern produced by the intersection of a northeast-trending syncline having an axial trace extending down the length of Attwood Lake and a northwest-trending cross-fold, the axis of which extends from the southeastern corner of the area to the northwestern corner of Weese Lake.

CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

If the reader wishes to convert imperial units to SI (metric) units or SI units to imperial units the following multipliers should be used:

CONVERSION FROM SI TO IMPERIAL			CONVERSION FROM IMPERIAL TO SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
			LENGTH		
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
			AREA		
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
			VOLUME		
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
			CAPACITY		
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
			MASS		
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
			CONCENTRATION		
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

1 ounce (troy)/ton (short)	20.0	pennyweights/ton (short)
1 pennyweight/ton (short)	0.05	ounce (troy)/ton (short)

NOTE–Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries published by The Mining Association of Canada in co-operation with the Coal Association of Canada.

Geology of the
Attwood Lake Area
District of Thunder Bay

by

Henry Wallace[1]

INTRODUCTION

The Attwood Lake area lies between Latitudes 51°12′N and 51°22′30′′N and from Longitude 88°20′W to Longitude 88°40′W, comprising approximately an area of 440 km^2. The centre of the area is about 120 km east-southeast of the town of Pickle Lake and 48 km southwest of the settlement of Fort Hope. During the summer of 1976, this area was mapped by a field party of the Ontario Geological Survey under the direction of the author. The survey concluded a program initiated in 1973 to update detailed geological information about, and to assess the potential for, future mineral exploration in the eastern part of the Uchi Subprovince (Wallace 1978a and b).

Acknowledgments

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Means of Access

Access into the area is restricted to float or ski-equipped aircraft which are available for charter from Pickle Lake, Armstrong, and Nakina. The Attwood Lake-Hurst Lake-Felsia Lake System and the Weese Lake System provide excellent water access to all but the northwestern corner of the map-area which can be reached from Vick Lake. All these lakes are suitable for use by even the

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largest float-equipped aircraft. Short portages are necessary for travelling between Attwood and Hurst Lakes and between Hurst and Felsia Lakes. The Witchwood River in the southeastern corner of the area is difficult to navigate by canoe because of numerous sets of rapids and low falls.

Although there are no permanent residents living in the area, sports fishing camps are located at the southern end of Attwood Lake and on the western side of Hurst Lake. Aircraft from Armstrong and Nezah (on Highway 11 near Jellicoe) service these tourist camps on a semi-regular basis during the summer.

History of Mineral Exploration

In the past, exploration in the Attwood Lake area has been limited by its remote location and poor accessibility, and by the paucity of geological information available. Although the area was prospected for gold in the late 1920s and 1930s, none of this work has been recorded, and so far as is known, no significant gold occurrences were found. Sporadic activity over the past 15 years has been directed toward the location of base-metal sulphide deposits within metavolcanics and mafic intrusions.

In 1961, Boylen Engineering Offices conducted a combined ground magnetic and electromagnetic survey between Attwood and Auger Lakes. This work followed up a previous airborne reconnaissance survey, and was part of a much larger exploration program including ground geophysics, geological mapping, trenching, and considerable diamond drilling, which was centred about 9 km northeast of Attwood Lake (Assessment Files Research Office, Ontario Geological Survey, Toronto).

In 1962, New Jersey Zinc Exploration Company (Canada) Limited carried out geological and ground geophysical surveys along the western side of Weese Lake. Anomalies and surface showings found during this work were investigated by diamond drilling in the winter of 1962-1963.

An airborne magnetic and electromagnetic survey that covered nearly all of the current map-area was performed for Canadian Onex Mines Limited in 1970 (Assessment Files Research Office, Ontario Geological Survey, Toronto).

In the spring and summer of the following year, diamond-drill holes were put down by Hudson Bay Exploration and Development Company Limited to investigate electromagnetic anomalies around the southern part of Attwood Lake and between Attwood and Hurst Lakes.

In 1972, Imperial Oil Enterprises Limited conducted ground magnetic and electromagnetic surveys over widely scattered grid systems around Attwood Lake (Assessment Files Research Office, Ontario Geological Survey, Toronto).

During the 1976 field season, the New Jersey Zinc Exploration Company (Canada) Limited was active in several parts of the area and undertook geological mapping and prospecting.

Previous Geological Work

The first geological mapping in this area was done by W.S. Dyer (1933) while making a reconnaissance survey which covered most of the eastern part of the Uchi Subprovince. In 1960, G.D. Jackson (1961) of the Geological Survey of Canada mapped a vast region which included the current map-area in conjunction with the "Roads to Resources" program. At the same time, V.K. Prest (1963) compiled a surficial geology map which covered this area. The only other published work to include this area was Operation Fort Hope, a large scale, helicopter-supported reconnaissance survey conducted by the Ontario Department of Mines in 1969 (Thurston and Carter 1970).

Aeromagnetic maps covering the map-area are available at a scale of 1:63 360 (ODM-GSC 1960a,b,c, and d).

Present Geological Survey

Geological mapping was carried out by a five-man field party between late May and early September 1976. About half of the area was mapped by pace-and-compass traverses run wherever possible normal to strike, spaced at approximately 400 m intervals. In areas where geological complexity was obviously minimal, and in areas where, on the basis of air photo interpretation and-(or) direct aerial reconnaissance, expected outcrop density was low, traverses were spaced from 800 m to 1500 m apart. The traverses were run between topographic features and across potential outcrop areas located on air photos. All outcrops along lakeshores, rivers, and trails were also examined.

Field data was recorded on transparent acetate overlays attached to black-and-white vertical air photographs at a scale of 1:15 840 (1 inch to ¼ mile) provided by the Silviculture Section, Public Service Centre, Ontario Ministry of Natural Resources. The information was later plotted at the same scale on cronaflex base map sheets supplied by the Cartographic Section, Division of Lands, Ontario Ministry of Natural Resources. Outcrop areas were generalized to allow for reduction of the map to the publication scale of 1:31 680 (1 inch to ½ mile).

Uncoloured preliminary maps of this area at a scale of 1:15 840 (1 inch to ¼ mile) were issued in 1977 (Wallace 1977a and b).

Natural Resources

The area is partly forested by stunted black spruce, balsam fir, and larch that grow in extensive sphagnum swamps. Jackpine, poplar, and white birch predominate in the better drained sandy areas. Large cedar, jackpine, and black spruce are common along lakeshores and riverbanks, but are uncommon elsewhere in the map-area.

Sports fishing for pickerel and pike is excellent in most of the lakes and connecting river systems in the area.

Fur-bearing animals appear to be numerous in the map-area. Species encountered by the field party include beaver, muskrat, otter, mink, marten, and fisher. Lynx and fox are also reported by travellers and residents from the region. No large animals were seen by the field party, but signs of moose or woodland caribou were frequently found.

Nesting water fowl were often seen along the river systems connecting the larger lakes. Common merganser and common goldeneye ducks were seen many times by members of the field party.

Physiography and Outcrop Distribution

Topographic relief within the map-area is relatively subdued. The highest point in the area is just east of Vick Lake where some outcrops are as much as 80 m above the level of Attwood Lake. The most rugged topography, however, is south of Vertente Bay where local outcrop relief is in the order of 25 to 30 m. Esker ridges north of the eastern arm of Weese Lake and south of Felsia Lake also have relief of about 25 m in places. Most of the area between Attwood and Felsia Lakes and between Weese and Attwood Lakes is very flat and low lying.

The northern part of the region is relatively well exposed (Map 2436, back pocket), particularly around the northern ends of Attwood and Hurst Lakes. However, the southern and central parts of the area are poorly to very poorly exposed even along lakeshores. Inland outcrops with a few exceptions are small, form low-ridges parallel to the strike of the rocks, and are separated from one another by swamp-filled linear depressions. Most shoreline outcrops on the major lakes are well exposed and well washed.

Drainage is poor in the central and southern parts of the map-area which are covered by extensive areas of swampy ground, small shallow ponds, and short, slow-moving intermittent streams. The local drainage pattern is generally oriented toward the east. The smaller lakes in the area including the Weese-Vick Lakes system drain into Attwood Lake which is also fed by the Attwood River from the southwest. Attwood Lake drains into Hurst Lake as does Felsia Lake which in turn is fed by the Witchwood River from the south. From Hurst Lake, which is the lowest water level in the area, water flows into the Attwood River System northeastward through a complex lake system and enters the east-flowing Albany River north of Frenchmans Rapids, north of the map-area. Auger Lake is not connected with the Attwood River System, but drains directly northward into Petawanga Lake on the Albany River.

GENERAL GEOLOGY

All bedrock in the map-area is believed to be Early Precambrian (Archean) in age. Most of the map-area is underlain by a northeast-trending belt of metavolcanics and metasediments which extends northeastward to connect with the main regional supracrustal belt of the Uchi Subprovince about 16 km north of Attwood Lake, (see Map 2237; Thurston, Carter, and Riley 1972). Except for

TABLE 1 | LITHOLOGIC UNITS FOR THE ATTWOOD LAKE AREA.

PHANEROZOIC

CENOZOIC

QUATERNARY

PLEISTOCENE AND RECENT

Till, sand, gravel (ground moraine and esker deposits).

Unconformity

PRECAMBRIAN

EARLY PRECAMBRIAN (ARCHEAN)

FELSIC TO INTERMEDIATE INTRUSIVE ROCKS

Biotite trondhjemite, biotite granodiorite, quartz diorite, porphyritic hornblende-biotite trondhjemite, porphyritic hornblende-biotite granodiorite, gneissic biotite granodiorite, biotite quartz monzonite, pegmatitic biotite quartz monzonite.

Relationship Uncertain

MAFIC INTRUSIVE ROCKS

Anorthosite, gabbroic anorthosite, anorthositic gabbro, gabbro, diorite, lamprophyre.

Intrusive Contact

METAVOLCANICS AND METASEDIMENTS

METASEDIMENTS

CHEMICAL METASEDIMENTS

Massive and banded ferruginous calc-silicate rocks, magnetite-quartz ironstone, siderite-quartz-epidote ironstone, chert.

CLASTIC METASEDIMENTS

Polymictitic pebble and cobble conglomerate, pebbly sandstone, granular sandstone, phyllite, quartz-feldspar-sericite schist; almandine-, staurolite-, andalusite-, sillimanite-, and cordierite-bearing sericitic and biotitic rocks, massive to schistose meta-wackes.

FELSIC TO INTERMEDIATE METAVOLCANICS

Massive and porphyritic flows, lithic tuff, crystal tuff, lapilli-tuff, lapillistone, tuff-breccia.

MAFIC TO INTERMEDIATE AND ULTRAMAFIC METAVOLCANICS

Pillowed and massive flows, amphibolite, pyroclastic rocks, migmatized metavolcanics, ultramafic flows.

this narrow connection, the local supracrustal rocks, which have been metamorphosed under amphibolite facies conditions, are in contact on all sides with extensive masses of felsic to intermediate plutonic and migmatitic rocks.

The oldest rocks are the metavolcanics which wrap around younger metasediments in the central part of the area in an apparently simple folded sequence. The metavolcanics, predominantly basaltic pillowed and massive flows, have been altered to amphibolites. In the northern and western parts of the area, however, these mafic flows are intermixed with units of andesitic to

rhyolitic pyroclastic rocks, mostly tuff to lapillistone, that in some sections are predominant. The lower several hundred metres of the clastic metasedimentary sequence, which rests conformably upon the metavolcanics, consist of polymictic conglomeratic rocks rich in metavolcanic clasts. The rest of the clastic sequence consists of almandine-, staurolite-, andalusite-, sillimanite-, and cordierite-bearing biotitic and sericitic metamorphic rocks apparently derived from wacke-type sedimentary rocks. Ferruginous chemical metasediments occur in several places close to the metavolcanic-metasedimentary interface.

West of Weese Lake, the supracrustal rocks have been intruded by a thick anorthositic sill which is continuous for several kilometres to the southwest of the area. Elsewhere in the map-area, mafic intrusive rocks are relatively uncommon and form only minor dikes.

The granitoid areas which all but surround the supracrustal sequence are predominantly trondhjemitic to granodioritic in composition. East of the supracrustal belt, the contact with granitoid rocks occurs over a broad zone containing a high proportion of strongly aligned metavolcanic inclusions. West and north of the supracrustal belt, the contacts with foliated granitoid rocks and gneisses are relatively sharp. Around the southern end of Attwood Lake, clastic metasediments are in gradational contact with migmatitic rocks consisting of remnant units of refractory biotite-rich rocks interlayered in variable proportions with, and intruded by, pegmatoid and granitoid quartz monzonitic material.

Several gabbroic dikes intrude the granitoid rocks around Hurst and Felsia Lakes. The relative and absolute ages of these bodies is unknown and it is possible that some are Middle Precambrian.

Most of the area is covered by a mantle of Pleistocene morainic sand and gravel deposits which are particularly thick in the southeastern corner.

Precambrian

EARLY PRECAMBRIAN (ARCHEAN)

Metavolcanics and Metasediments

METAVOLCANICS

In this report, metavolcanics are subdivided first into two major compositional categories on the basis of colour index, the amount of dark coloured minerals in a rock expressed in volume percent, which was assessed during the field work and subsequent laboratory examination. Rocks classified as "felsic to intermediate" are characterized by colour indices less than 20 percent and include rocks of rhyolitic, rhyodacitic, and dacitic composition as well as some metavolcanics of andesitic composition. "Mafic to intermediate" metavolcanics have colour indices greater than 20 percent and include all basalts and most

andesitic rocks. Ultramafic metavolcanics in this area were recognized on the basis of their distinctive mineralogy, and texture as well as their mesoscopic structural features. Classification of these rocks was done more rigorously using chemical criteria (see the section on "Petrochemistry").

Metavolcanics underlie much of the northeastern, west-central, and eastern parts of the map-area. Although metamorphic rank and the degree of tectonic deformation has been moderately high, primary features such as pillows, individual pyroclastic fragments, amygdules, and so on are readily discernible in most places.

Between Attwood and Hurst Lakes, the metavolcanics are almost exclusively mafic pillowed flows. Eastward across Hurst and Felsia Lakes, this succession grades into a mixed sequence of pillowed and massive mafic flows and felsic to intermediate flows and pyroclastic units. There, the relative proportion of mafic and felsic rocks is obscured by the intrusion of granitoid material, but mafic flows appear to predominate. Numerous large metavolcanic inclusions occur within the Hurst Lake Batholith (see section on "Felsic to Intermediate Intrusive Rocks") for at least 2 km east from the contact with the main mass of metavolcanics.

The thick volcanic sequence which extends from Auger Lake to Weese Lake consists of mafic to intermediate (mostly basaltic) pillowed and massive flows interlayered with intermediate to felsic pyroclastic rocks, that are mostly dacitic to rhyolitic lapilli-tuff and lapillistone. The interlayering is generally on the scale of only a few metres, and the relative proportions of mafic and intermediate to felsic units appears quite variable both laterally and across strike. Intermediate to felsic pyroclastic rocks predominate in some areas, including an exceptionally thick mixed sequence north of Weese Lake. Along the contact with the Vick Lake Batholith to the north, the metavolcanics have become granoblastic gneisses and are migmatized in places.

Between Weese and Attwood Lakes, pillowed mafic flows are again predominant, but on the northwest side of Attwood Lake, there are at least three major pyroclastic sequences within the mafic metavolcanics and metasediments. These pyroclastic sequences consist mostly of rhyolitic to dacitic tuff, lapillistone, and lapilli-tuff.

A considerable area east of the central part of Attwood Lake is believed to be underlain by felsic to intermediate pyroclastic rocks, but outcrop exposure is minimal, and the dimensions of the zone are not well defined.

Mafic to Intermediate and Ultramafic Metavolcanics

PILLOWED AND MASSIVE FLOWS

Pillowed flows and fine-grained massive flows constitute the bulk of the mafic metavolcanics. Most of these rocks are basaltic in composition, but andesitic flows are common in the Auger Lake-Weese Lake sequence.

Although most pillowed flows are fine grained to aphanitic, pillows have been recognized in medium- to coarse-grained amphibolite units. Generally,

pillow packing is tight, and selvages are thin (0.5 to 1 cm) and low weathering. Individual exposed pillows commonly range from 0.3 to 1.0 m in length with axial ratios from 1:1 to 8:1; but in one unit north of Vertente Bay, there are pillows up to 5 m long by 0.5 m thick. Quartz-filled amygdules are common in pillowed units throughout the area, in some cases forming up to 10 percent of the rocks. Also common are ellipsoidal to irregular felsic masses, typically dacitic in composition, enclosed within individual basaltic or andesitic pillows. These masses may constitute from 10 to 70 percent of the pillow volume. Although contacts around these felsic domains appear relatively sharp on the weathered surface, the change in composition takes place over 2 to 4 cm.

On most weathered surfaces, the mafic pillowed flows are dark green, or even black where glacial polishing is pronounced. The very dark selvages weather preferentially, clearly outlining individual pillows, but the felsic domains are resistant, forming light grey or green bomb-like features. Rusty weathering, presumably reflecting abnormally high iron sulphide concentrations in the rocks, is quite common between Attwood and Hurst Lakes. Garnet crystals up to 5 mm across occur in many pillowed units and are commonly concentrated in or near the selvages.

Brecciated flow tops containing pillow fragments were recognized in several mafic units between Attwood and Hurst Lakes and south of Vertente Bay, but obvious flow contacts were only rarely observed in wholly mafic successions. Flow thicknesses were difficult to assess in those places, but where pillowed or massive flows were intercalated with readily distinguishable felsic to intermediate pyroclastic units, the flows were found to be 2 to 6 m thick.

Massive flows are generally featureless, but flow top breccias and isolated pillows were observed in these units in a few locations. This confirms their extrusive origin. In these units too, amygdules are very common, but their distribution across individual flows was rarely useful as an indication of tops. Plagioclase varioles up to 3 mm across occur in a few massive flows around Vertente Bay.

Some massive units exhibit vague, semi-continuous layering, with layers 1 to 2 cm thick. These may represent originally flow-banded units. In other units, metamorphism and deformation have resulted in the development of flaser-like structures.

Petrographic examination of these rocks has shown them to have a very simple mineralogy. All the examined thin sections contain dark green hornblende (30 to 80 percent), plagioclase (An_{35-55}) (20 to 40 percent), quartz (5 to 20 percent), iron-titanium oxides (2 to 5 percent), with sphene, garnet, and apatite as common accessories. Epidote, although absent in many sections, formed up to 10 percent of others. Carbonate is abundant in several thin sections. Biotite and sericite were rarely observed. No chlorite occurs in any of the thin sections examined.

Texturally, however, considerable variety was evident among the mafic metavolcanics studied microscopically. Although a few examples contain scattered plagioclase phenocrysts and others contain large hornblende porphyroblasts, most of these rocks are roughly equigranular and even textured. Many are well foliated, with strong alignment of hornblende prisms parallel to quartz ofeldspathic lenses. Other samples exhibit compositional banding on a microscopic scale, in which the texture and composition (the hornblende/plagioclase

ratio, vary markedly between bands. Some of the rocks are without foliation and exhibit random patchy arrangements of feathery hornblende which in some cases have taken the form of stellate bundles. Granoblastic textures occur in rocks adjacent to the surrounding batholiths.

AMPHIBOLITE

Medium- to coarse-grained rocks were classified simply as amphibolites where no definitive mesoscopic features such as pillows, amygdules, tephra, and so on were observed to establish their mode of origin. Although most of these rocks were certainly derived from mafic flows, the progenitors of some of these amphibolites were probably mafic pyroclastic rocks, mafic intrusions, and possibly even ferruginous chemical metasediments (see section on "Massive and Layered Ferruginous Calc-Silicate Rocks" in the section "Chemical Metasediments").

The massive amphibolites with average grain size of 2 to 5 mm are essentially featureless, weather dark green to black, and typically have a rough pitted surface. Mineral foliation and jointing are well developed in some outcrops, but absent in others. Garnet contents of up to 15 percent are common. In some cases the garnets occur preferentially in discrete zones giving the rock a layered appearance, but in most units they are uniformly scattered.

Rocks classified as layered amphibolites include originally massive flows and possibly sills which have taken on a gneissic layering due to metamorphic differentiation, and mafic to intermediate pyroclastic rocks which were originally bedded or in which bombs have been greatly attenuated to form parallel lenses resembling semi-continuous layers. Both of these types of layered amphibolite occur in the Vertente Bay-Auger Lake area, particularly in the vicinity of the contact of the metavolcanics with the Vick Lake Batholith (see section on "Felsic to Intermediate Intrusive Rocks"). Layers are generally in the order of 1 to 5 cm wide; adjacent layers vary greatly in colour, mineralogy, grain size, texture, weathering characteristics, and so on. Commonly, the layered rocks derived from the originally bedded or fragmental rocks exhibit sharper and more regular layering, but the distinction between the two types is impossible in many cases.

PYROCLASTIC ROCKS

Mafic to intermediate pyroclastic rocks are relatively uncommon in the map-area. Andesitic tuff and lapilli-tuff units occur intercalated with felsic pyroclastic rocks and mafic flows in the northwestern part of the Weese Lake-Auger Lake sequence. Thin mafic to intermediate tuff to tuff-breccia units are only rare components in the metavolcanic sequences elsewhere in the map-area.

Individual tephra are difficult to delineate in most of these rocks, as the colour indices and general weathering characteristics of the fragments and surrounding matrix material are similar. Only in a few places has differential

weathering enhanced the fragmental nature of these rocks. Even when fragments are identifiable, it is not always possible to distinguish between a pyroclastic and an autoclastic origin because of tectonic deformation.

Mineralogically, the pyroclastic rocks contain considerably more carbonate minerals, epidote, and biotite than the flow rocks described previously. The pyroclastic rocks also contain secondary (retrograde) chlorite which appears to be absent in the flows. In thin section also, it is commonly impossible to distinguish individual fragments. In some examples, however, this can be done because of the variation in the proportion of hornblende, biotite, and chlorite between adjacent ash or small lapilli-sized fragments. Vague, wispy quartzofeldspathic lenses detected in some thin sections appear to be felsic lithic fragments, but they constitute only minor components of these rocks.

MIGMATIZED METAVOLCANICS

Mafic to intermediate metavolcanics in the vicinity of the Vick Lake Batholith are commonly migmatized. The metavolcanic phases are medium-grained granoblastic amphibolites which generally appear massive or vaguely gneissic. These rocks are typically rich in epidote (10 to 20 percent).

The neosome, which forms anywhere from 10 to 80 percent of these migmatitic rocks generally occurs as sub-concordant stringers and lenses. The buff to pale pink neosome appears to be quartz monzonitic in most outcrops. It is commonly foliated and varies greatly in grain size from aplitic to pegmatitic over short distances.

The metavolcanic paleosome and the neosome in many outcrops have been intermixed by complex folding. Both phases are cut by quartz veins which are numerous near the margins of the Vick Lake Batholith.

ULTRAMAFIC METAVOLCANICS

Only two exposures of ultramafic rock were found in the map-area. One is on the eastern side of Attwood Lake near the narrows at the northern end, and the other is on the northeastern corner of the eastern arm of Weese Lake. These two outcrops are different in appearance, but both are believed to be parts of extrusive units. Both exposures are small and no contacts were exposed, so the dimensions of these bodies were not determined.

The first mentioned exposure consists of peridotitic komatiite (see section on "Petrochemistry"). Its weathered surface is light grey-green and is exceptionally rough. A prominent feature of the outcrop is polysuturing, which is a series of distinctively formed joints characteristic of ultramafic flows (Photo 1). The eastern edge of the outcrops appears to be a coarse flow-top breccia, but the rest is quite massive, even grained, and even textured. Finely disseminated pyrrhotite forms about 1 to 2 percent of the rock.

Thin section examination reveals that this rock consists of felted masses of fine- to coarse-grained acicular tremolite and serpentine with small amounts of

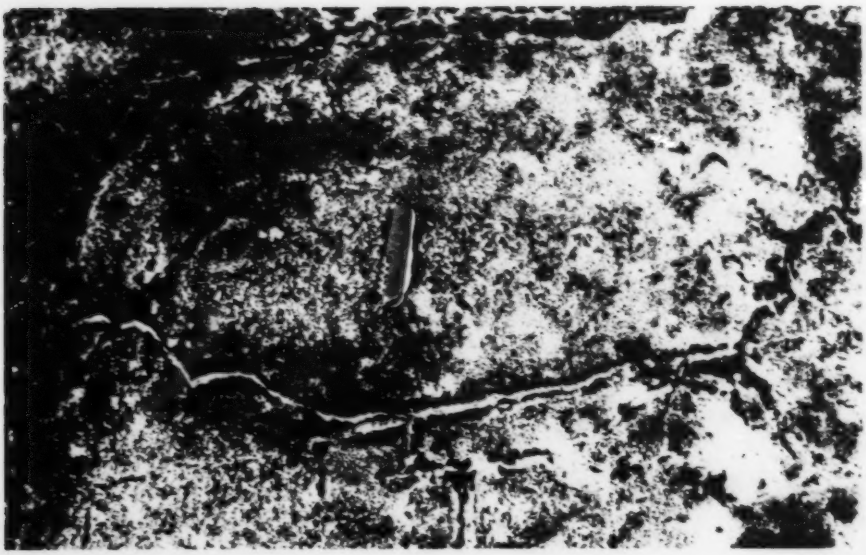

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Photo 1–"Polysutured" joints in the ultramafic flow exposed on the peninsula just east of the narrows in northern Attwood Lake.

talc, very fine grained magnetite, and highly variable amounts of carbonate which occur in large irregular patches. A few subhedral to euhedral pseudomorphs of serpentine after olivine were also recognized.

The second ultramafic occurrence found by the field party consists of basaltic komatiite. On the weathered surface this rock is dark green and has a pronounced flaser texture. Faint polysutured joints or pillow-like features were also found in this outcrop; but the evidence for its extrusive origin is not unequivocal.

In thin section, this rock consists of large (1 to 2 cm), commonly poikiloblastic porphyroblasts of tremolite-actinolite surrounded by a strongly foliated matrix of fine-grained tremolite, serpentine, iron-titanium oxides, and plagioclase. Some of the porphyroblasts are rich in magnetite dust which commonly forms patterns outlining euhedral magnetite-free patches after olivine.

Felsic to Intermediate Metavolcanics

MASSIVE AND PORPHYRITIC FLOWS

Flows of rhyolitic to dacitic composition are rare in the map-area. Most of them occur around Hurst Lake in the contact zone with the Hurst Lake Bathol-

ith, and in some cases form large inclusions within that intrusion. Pyroclastic rocks similar in composition and appearance are common in this area.

The flows are generally very hard and resistant to weathering, forming prominant massive outcrops with smooth porcellaneous surfaces. Most of the units are markedly porphyritic; high weathering quartz and plagioclase phenocrysts up to 5 mm across form up to 30 percent of the rock. Other flow units are predominantly aphanitic. Some of these exhibit flow banding produced by variations in ferromagnesian content between laminae which are 0.5 to 1.0 cm thick.

In thin section, these rocks are even textured. Most have a weak sericitic foliation which is deflected by quartz and oligoclase phenocrysts. The plagioclase grains are typically equant and subhedral, but quartz phenocrysts are commonly embayed by the surrounding very fine grained quartzofeldspathic matrix which contains little chlorite and(or) biotite, and no amphibole.

A few felsic units which appear to be flows occur in the mixed metavolcanic sequence around Auger Lake. Most of these resemble the rocks described in the previous section, but units of brecciated rhyolitic material were also found by the field party. One aphanitic flow of dacitic composition found north and south of Vertente Bay may be pillowed.

PYROCLASTIC ROCKS

Pyroclastic rocks, fine lithic tuff to tuff-breccia constitute the bulk of the felsic to intermediate extrusive rocks in this area.

In the mixed metavolcanic sequence extending from Auger Lake, through Vertente Bay toward Weese Lake, felsic to intermediate pyroclastic units are intimately intercalated with mafic, pillowed, and massive flows and pyroclastic units. Most of the felsic pyroclastic units are less than 2 m thick, but a few are up to 8 m thick. Lithic tuff and fine lapilli-tuff are most abundant, but crystal tuff rich in white, subhedral oligoclase grains is also common. All of these rock types are commonly found interbedded on a fine scale.

In most units tephra appear to have been considerably flattened. This probably occurred prior to tectonic deformation since pillows and amygdules in flows nearby are relatively mildly deformed. Typically, the lapilli-sized fragments are light grey aphanitic rhyolite to dacite, and the surrounding matrix is a darker, coarser grained andesitic to dacitic rock. In thin section, most of these rocks appear to be severely recrystallized, but direct evidence of their pyroclastic origin is found in the form of bent and broken plagioclase crystals and in recognizable lithic fragments that are outlined by the biotite-sericite foliation.

West of the north-central part of Attwood Lake, felsic to intermediate pyroclastic rocks form at least three major lenses which include very few mafic intercalations. Within these lenses, there is a wide variety of rock types in terms of chemical composition, fragment size and type, and bedding characteristics. Units of finely bedded lithic tuff, which are rhyolitic to rhyodacitic in composition, contain scattered lapilli, and form prominent outcrops along the western side of Attwood Lake south of the narrows. In the same area, there are monolithic lapillistone units containing up to 90 percent porcellaneous rhyolitic

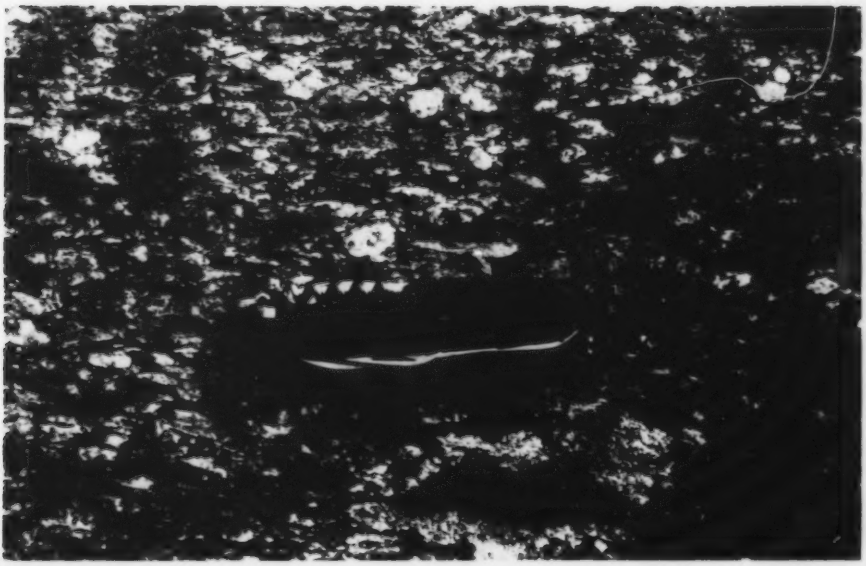

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Photo 2–Rhyolitic monolithic lapillistone from the small islands in the narrows of northern Attwood Lake.

fragments, and dacitic to andesitic lapilli-tuff to tuff-breccia units consisting of low weathering, light grey dacitic fragments in a coarse-grained garnetiferous amphibolite matrix. Other dacitic units are also rich in garnets, but the fragments and matrix are similar in composition.

On the small islands at the narrows in Attwood Lake there is a sequence of essentially monolithic lapilli-tuff and lapillistone units (Photo 2) which exhibit excellent graded bedding. The fragments, which are cherty, light grey to white and angular, weather very high relative to the more mafic matrix. On the peninsula to the east of these islands, outcrops consist predominantly of bedded and massive lithic tuff probably dacitic to andesitic in composition. Monolithic dacitic lapilli-tuff units occur intermixed with the finer tuff, but fragments appear contorted and are difficult to distinguish with certainty.

Inland northwest of Attwood Lake, individual pyroclastic units are less easily identified since contacts are rarely exposed. Considerable thicknesses of monolithic and heterolithic (Photo 3) lapillistone and lapilli-tuff are massive and monotonous, but rare units of bedded lithic and crystal tuff found in these sequences probably indicate that many distinct coarse pyroclastic units are involved.

Felsic crystal tuff and tuff-breccia form some of the large inclusions found on the eastern side of Hurst Lake within the Hurst Lake Batholith. The crystal tuff resembles the rhyolitic porphyritic flows in the same area, but these have weathered to form a more irregular surface and contain rare lapilli. Many of these units occur in contact with mafic flows or pyroclastic units, but both con-

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Photo 3–Heterolithic lapillistone from just west of the narrows in northern Attwood Lake. Fragments range in composition from rhyolitic to basaltic, but most are dacitic.

tacts are rarely seen, and the dimensions of the pyroclastic beds are uncertain. The tuff-breccia units consist of aphanitic rhyolitic to rhyodacitic angular bombs in a crystal-rich dacitic matrix.

The felsic metavolcanics east of the central part of Attwood Lake, are very poorly exposed except for the large lakeshore outcrops. These outcrops consist of clean, white, homogeneous, fissile, yet very hard rhyolite. In the field, there is little convincing evidence of its origin. Most of the rock is a sugary mosaic of quartz and feldspar with scattered subhedral plagioclase and microcline phenocrysts. Obvious fragments were lacking, and no bedding or flow banding were recognized. In thin section, however, a strong sericitic foliation imparts a fine discontinuous layering to the rock which resembles highly flattened lapilli-sized lithic fragments. The overall ferromagnesian mineral content composed of biotite and chlorite is very low, and varies noticeably between these layers and vaguely outlines oblate ellipsoidal fragments.

The only other exposures of felsic metavolcanics in this part of the area, occur about 600 m inland from the rocks just described. These outcrops, at 51°15′N and 88°28′W, are made up of: massive very fine grained white lithic tuff in which the odd flattened lapilli can be discerned; and easily recognizable lapilli-tuff units.

Petrographic examination shows that felsic pyroclastic rocks from all parts of the area consist of quartz, plagioclase, muscovite, biotite, and (or) chlorite. Small amounts of epidote and iron-titanium oxides also occur in many thin sections. Garnets are common in the rocks from the northwestern side of Att-

wood Lake. Microcline was only found as phenocrysts in the tuffs from the southeastern end of Attwood Lake. Patches of carbonate form generally less than 5 percent of the minerals present in the thin sections examined.

Oligoclase is the dominant crystal phase in these rocks. It generally forms equant subhedral grains up to 0.5 cm across. Microcline crystals, where they occur, are similar in size and form. Subhedral quartz phenocrysts are less common than plagioclase, and are less abundant where the two phases occur as phenocrysts in the same rock.

The prominence of sericitic and biotitic foliations varies greatly in the samples examined. In many thin sections, the foliation patterns distinctly outline lithic clasts, and commonly this is the only way to recognize individual tephra in thin sections of essentially monolithic pyroclastic rocks. In heterolithic samples it is possible to identify fragments from differences in their textures, phenocryst content, and ferromagnesian content.

In the more intermediate pyroclastic rocks, hornblende and tremolite-actinolite occur with or without biotite. Epidote and iron-titanium oxides are far more abundant in these rocks than in those described above.

Petrochemistry

The locations of sampling sites of chemically analysed metavolcanic rocks are shown in Figure 2. Complete whole rock analyses of these metavolcanics are listed in Table 2. All analyses were performed by the Geoscience Laboratories, Ontario Geological Survey. Samples were selected for analysis to confirm field identifications and to assess the chemical affinities of volcanism in this region.

Figure 3 includes an AFM and Jensen Cation Plot (Jensen 1976) of the analyses listed in Table 2. From these plots, the following observations were made:

1) In this area, the composition of the metavolcanics could be estimated quite accurately on the basis of hand specimen examination in the field.
2) According to both plots, rocks of andesitic composition were uncommon. The bimodal-grouping of the rocks analysed was believed to be a real phenomenon rather than a product of sampling bias.
3) Komatiitic flows from this area plot in distinct fields on both diagrams, removed from the tholeiitic and calc-alkaline trends.
4) Rocks consisting of amphibole and garnet, suspected of having been derived from ferruginous chemical metasediments, but resembling mafic amphibolite of metavolcanic origin, plotted well outside the common volcanic fields on both diagrams. This strongly reinforced the field classification made by the field party.
5) Overall, the Attwood Lake metavolcanics appear to fall closer to the calc-alkaline than the tholeiitic series as defined by T.N. Irvine and W.R.A. Baragar (1971) and L.S. Jensen (1976), but there is a distinctly bimodal grouping of sample compositions and few data points lie

TABLE 2 | COMPLETE CHEMICAL ANALYSES OF METAVOLCANICS FROM THE ATTWOOD LAKE AREA. ANALYSES BY THE GEOSCIENCE LABORATORY, ONTARIO GEOLOGICAL SURVEY.

Locality Number	Rock Type (field name)	Major Components in Weight Percent															
		SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	S	MnO	CO_2	H_2O+	H_2O-	Total
1	Intermediate flow	58.5	14.9	4.41	2.84	1.83	13.8	0.16	0.06	1.09	0.09	0.01	0.16	0.07	0.44	0.22	98.6
2	Mafic flow	54.0	15.2	1.99	8.66	5.86	6.45	4.01	0.07	1.23	0.11	0.01	0.21	0.10	0.19	0.32	98.4
3	Mafic flow	53.5	14.6	2.61	8.73	5.51	7.09	1.62	0.86	0.78	0.08	0.84	0.39	0.22	0.99	0.28	98.2
4	Mafic amphibolite	49.7	18.2	1.74	6.83	8.30	11.2	1.65	0.11	0.90	0.07	0.01	0.15	0.08	0.75	0.16	99.8
5	Felsic flow	67.8	16.2	0.93	2.46	1.41	1.92	5.21	1.46	0.53	0.13	0.03	0.03	0.24	1.22	0.19	99.7
6	Felsic flow	67.0	15.9	1.00	1.62	1.20	2.35	5.14	2.14	0.45	0.10	0.05	0.03	0.70	0.50	0.22	98.4
7	Intermediate tuff	66.5	16.2	0.77	1.95	1.48	3.09	4.80	2.61	0.34	0.08	0.01	0.05	0.80	0.47	0.21	99.4
8	Mafic flow	46.9	15.2	2.30	9.14	8.15	13.3	1.65	0.07	0.66	0.06	0.07	0.20	0.15	0.94	0.20	99.0
9	Mafic amphibolite	47.1	15.1	2.00	10.8	8.00	10.3	2.31	0.28	1.09	0.08	0.04	0.22	0.07	1.40	0.19	99.0
10	Mafic flow	48.7	14.8	2.10	10.4	8.49	8.97	3.30	0.14	0.94	0.08	0.03	0.20	0.10	0.85	0.22	99.3
11	Mafic flow	48.3	15.1	1.50	10.5	8.13	7.66	3.79	0.16	0.03	0.08	0.02	0.19	1.09	0.05	0.25	98.8
12	Mafic flow	45.9	15.0	2.00	11.1	9.19	9.73	2.73	0.15	1.14	0.06	0.01	0.22	0.08	1.15	0.31	98.8
13	Ultramafic flow	43.3	7.29	1.78	8.31	25.7	5.42	0.09	0.01	0.24	0.05	0.06	0.15	2.83	4.65	0.25	100.1
14	Ultramafic flow	39.0	11.5	4.75	6.35	25.1	5.82	0.01	0.01	0.23	0.08	0.08	0.14	1.55	6.33	0.33	101.3
15	Felsic tuff	71.3	15.2	0.51	2.03	0.76	3.23	3.71	1.23	0.44	0.08	0.01	0.08	0.13	0.27	0.17	99.1
16	Felsic lapillistone	73.4	13.9	0.44	1.87	0.67	2.60	3.13	1.40	0.30	0.07	0.01	0.11	0.27	0.66	0.24	99.1
17	Mafic lapilli-tuff	49.2	13.5	2.50	10.4	7.36	10.3	2.48	0.27	1.03	0.08	0.01	0.26	0.07	0.58	0.25	98.3
18	Intermediate tuff	57.4	13.9	1.71	6.47	1.81	5.92	3.98	1.52	0.44	0.12	0.01	0.45	3.40	1.17	0.24	98.5
19	Magnetitic amphibolite*	45.2	10.8	4.30	15.8	6.30	9.53	1.37	0.18	2.91	0.12	0.05	0.27	0.07	1.51	0.19	98.6
20	Felsic Lapilli-tuff	75.5	12.2	1.66	1.84	0.43	1.14	3.36	1.74	0.23	0.03	0.01	0.05	0.53	0.52	0.22	99.5

21	Felsic flow	76.4	12.9	0.62	0.40	0.04	0.78	6.40	0.48	0.04	0.04	0.18	0.01	0.10	0.23	0.21	98.8
22	Felsic flow	73.9	14.8	0.51	0.49	0.17	0.60	4.76	3.18	0.02	0.02	0.01	0.03	0.27	0.19	0.20	99.1
23	Mafic flow	53.5	16.3	2.21	6.75	4.61	8.32	3.28	0.49	1.11	0.16	0.02	0.15	0.35	1.17	0.30	98.7
24	Felsic tuff	74.4	14.3	0.87	0.68	0.71	1.33	1.98	3.70	0.18	0.06	0.01	0.08	0.08	0.67	0.33	99.4
25	Felsic lapilli-tuff	74.4	14.8	0.69	0.63	0.66	0.78	2.32	3.78	0.18	0.09	0.03	0.06	0.05	0.66	0.29	99.4
26	Ultramafic flow	45.4	12.2	1.70	11.3	17.4	7.44	0.77	0.04	0.40	0.08	0.10	0.23	0.11	3.26	0.20	100.6
27	Mafic flow	53.5	14.6	2.61	8.73	5.51	7.09	1.62	0.86	0.78	0.07	0.84	0.39	0.22	1.06	0.28	98.2
28	Garnetiferous amphibolite*	46.1	13.2	2.20	16.3	7.43	9.51	0.67	0.09	0.73	0.03	0.01	0.69	0.20	0.93	0.19	98.3
29	Mafic flow	48.4	14.8	2.50	10.9	6.75	9.84	3.09	0.14	1.54	0.10	0.01	0.21	0.07	0.62	0.25	99.2
30	Mafic tuff	52.8	15.3	3.10	8.65	4.98	8.84	2.76	0.22	1.50	0.11	0.04	0.14	0.07	0.47	0.20	99.2
31	Intermediate tuff	54.6	16.4	2.26	5.28	2.86	7.77	3.63	1.25	1.16	0.23	0.01	0.15	1.40	1.04	0.28	98.3
32	Massive amphibolite*	46.3	12.7	6.20	20.3	4.13	5.67	0.62	0.14	0.78	0.06	0.15	0.50	0.08	0.81	0.33	98.8
33	Massive amphibolite*	48.0	11.5	2.00	16.6	6.41	9.21	1.07	0.15	1.54	0.10	0.02	0.61	0.01	0.65	0.35	98.2
34	Anorthosite	46.7	29.9	0.66	2.21	2.61	15.0	1.93	0.04	0.21	0.02	0.01	0.05	0.07	0.21	0.15	99.8

* = Ferruginous Chemical Metasediments

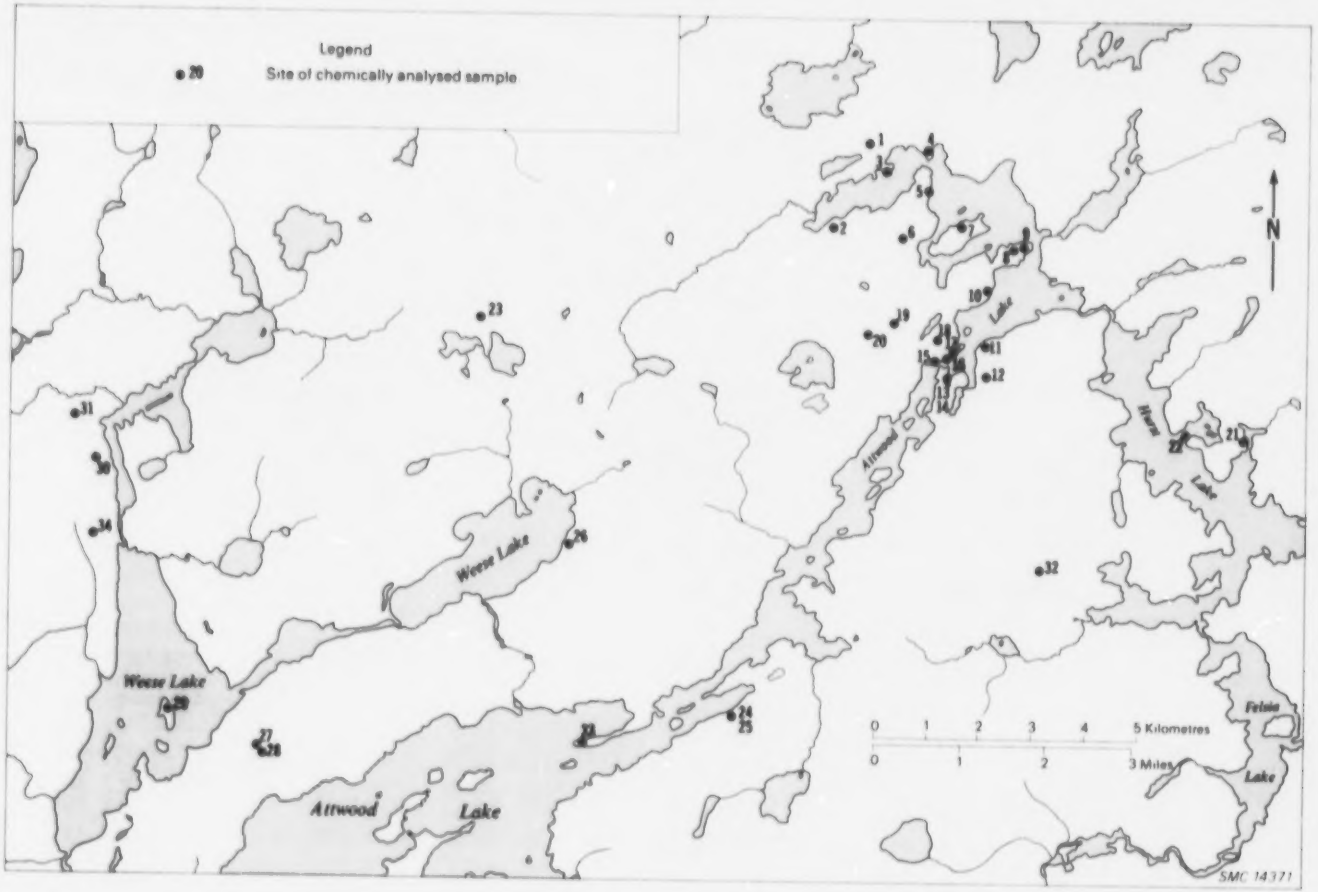

Figure 2–Collection sites of chemically analysed samples. Numbered analyses listed in Table 2 correspond to the numbered sites given on the figure.

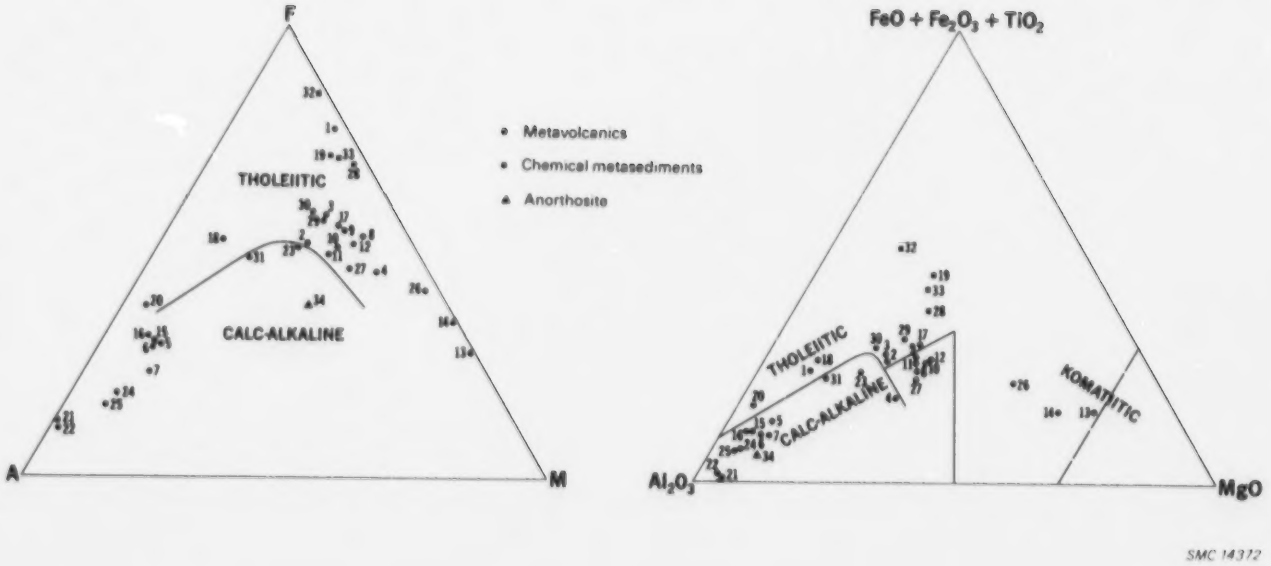

Figure 3–AFM and Jensen Cation Plots of chemical analyses given in Table 2.

between the tholeiitic basalts, both high magnesian and high iron, and the calc-alkaline rhyolites.

6) The most felsic rocks analysed are rhyolite flows from the eastern side of Hurst Lake (analyses 21 and 22; see Table 2) and rhyolitic pyroclastic rocks from the southeastern side of Attwood Lake (analyses 24 and 25; see Table 2).

METASEDIMENTS

Clastic Metasediments

The clastic metasediments in the Attwood Lake area appear to be concentrated in the sequence located around central, southern, and northern Attwood Lake. Intercalations of clastic metasediments in the metavolcanics surrounding this sequence are rare, with the only notable example being the metasediments which occur along the western side of Weese Lake.

Most of the clastic metasediments in the area appear to have been metawackes initially, but were metamorphosed to become almandine-, staurolite-, sillimanite-, andalusite-, and cordierite-bearing quartz-feldspar-biotite rocks. Fine-grained phyllitic rocks and quartz-feldspar-sericite schist believed to be metamorphosed mudstone, commonly form intercalations with the metawackes and in some outcrops are predominant. The lower 1000 m of the main metasedimentary sequence contains a high proportion of conglomeratic rocks, which are not common through the rest of the sequence. Such conglomeratic rocks also form a wedge about 300 m thick between metavolcanic successions on the northwestern side of Attwood Lake.

Conglomeratic Rocks

Conglomeratic rocks are well exposed on the peninsula east of the narrows in northern Attwood Lake and in many inland outcrops in that area. The rock types found vary from polymictic cobble and pebble conglomerates, both clast- and matrix-supported, to pebbly and granular sandstone.

The coarsest rocks in terms of clast size occur in the vicinity of the narrows. Bedding there appears to be quite massive. Contacts between units and clast size gradation are rarely observable. Clasts up to boulder size occur in some outcrops, but most are cobbles with the shape of oblate spheroids. The clast-matrix relationship has been obscured by differential clast deformation and metamorphism. On most weathered surfaces, granitoid clasts are prominent, being the largest, least deformed and altered, and most easily recognizable rock type present. Quartz clasts are also easily identifiable being equant and irregular in shape. Clasts of other rock types, however, are less easily seen. On fresh surfaces and in thin section, clasts of meta-sandstone and mudstone, chert, quartz-magnetite ironstone, mafic metavolcanic amphibolite and intermediate to fel-

sic metavolcanics, (porphyritic and aphanitic), are recognizable with varying degrees of difficulty.

Although granitoid fragments commonly have axial ratios in the order of 1:1:1 to 2:1:1, the metasedimentary and mafic and intermediate metavolcanic clasts are typically highly flattened, for instance axial ratios are in the order of 8:4:1, and form both a lineation and a strong foliation. In colour, texture, and weathering characteristics, many of the metasedimentary and metavolcanic clasts are similar to each other and to the matrix material. This, as well as their lack of distinctive shape makes many such clasts blend together with the fine-grained matrix so that it appears that the granitoid cobbles are suspended in a fine-grained matrix forming a paraconglomerate. In fact, most closely examined units are almost certainly orthoconglomerates with high proportions of cobble and pebble-sized metasedimentary and metavolcanic fragments, particularly the latter.

Proportions of the various clast types are difficult to estimate. In the coarser conglomerates, granitoid clasts, trondhjemitic to granodioritic in composition, typically form 10 to 20 percent of the rock. Felsic to intermediate metavolcanic clasts form another 20 to 30 percent, mafic metavolcanics up to 40 percent, and clastic metasediments appear to constitute about 5 to 10 percent. Quartz, chert, and ironstone together make up less than 1 percent in most outcrops. In pebble conglomerates and pebbly and granular sandstone units, the proportion of granitoid clasts, which are still commonly the largest in terms of size, is considerably lower, generally less than 5 percent. Metavolcanic pebbles, particularly felsic to intermediate pebbles and sandstone pebbles are predominant in these finer conglomeratic rocks. In these units, bedding in the order of 10 cm to 2 m is common. Typically pebbly sandstone units are separated by beds of coarse sandstone or granular sandstone, but contacts between conglomerate beds are also commonly observed. Small scale crossbedding, graded bedding, and other depositional features were recognized in some of these units, but most appeared to be poorly sorted and massive.

The matrix material in the conglomeratic rocks is a dark green to light grey, fine to coarse grained, schistose meta-sandstone which commonly contains garnet and staurolite porphyroblasts. Some porphyroblasts can be seen to transect matrix-clast boundaries, and in many cases they are aligned parallel to the rodding of clasts. In thin section, the matrix generally consists of quartz, plagioclase, biotite, chlorite, hornblende, and magnetite. The total ferromagnesian mineral content is high, between 20 to 35 percent, much higher than in most clasts. Biotite and chlorite give rise to well developed foliations in the matrix, but biotite also forms large porphyroblasts similar in size to those of garnet and staurolite.

In some examples, the matrix exhibits a distinct bimodal quartz and feldspar grain size distribution. Overall, the matrix component in conglomeratic rocks appears to be meta-lithic and feldspathic wacke. As mentioned previously, the boundaries between clasts and matrix appear to be gradational in many cases because of metamorphism, but the contrasts in texture, grain size, and mineralogy make clasts obvious in most thin sections.

PHYLLITE AND QUARTZ-FELDSPAR-SERICITE SCHISTS

Phyllitic mudstone units and slightly coarser grained quartz-feldspar-sericite schist units also believed to be derived from mudstone occur alone in thick sequences, and are intercalated with meta-wacke and conglomeratic units in the central part of the area. These phyllitic rocks commonly appear to be massive over a length of several metres across strike, but in other outcrops bedding on a fine scale, commonly intricately folded, is visible. Along the western side of Attwood Lake, these rocks are highly fissile, and in many outcrops closely spaced crenulation and kink bands impart a strong secondary foliation to the rocks. Numerous quartz veins commonly parallel these features.

Euhedral to ellipsoidal porphyroblasts of staurolite and large biotite "books" are common in these rocks, forming up to 10 percent of some outcrops. The porphyroblasts weather black and relatively high, standing out sharply from the light grey soft phyllitic matrix. Garnet and andalusite metacrysts are far less common.

In thin section, these rocks are characterized by a very strong sericitic foliation. Large opaque flakes and helicitic porphyroblasts of staurolite and biotite generally parallel the foliation, but large chlorite flakes are randomly oriented, appearing to have formed later than the dominant planar texture. Kink banding and micro-crenulation commonly produce undulatory optical effects in the foliation and in many cases are seen to deform biotite porphyroblasts. Micro *en echelon* tension gashes also occur subparallel to the kink bands.

In some massive-looking phyllitic rocks, thin section examination reveals indistinct bedding only a few millimetres thick. The porphyroblasts are commonly concentrated in some laminae, but staurolite grains may overgrow several units.

META-WACKES

Metamorphic rocks derived from wackes form the bulk of the metasedimentary sequence around central and south Attwood Lake. Most of these rocks are not true schists or gneisses. Bedding is obvious in most of these rocks, and mineral foliation is generally only moderately developed; typical phyllosilicate contents range from 15 to 25 percent. However, nearly all of these rocks are substantially changed in terms of texture and mineralogy from their inferred original condition, and have been classified according to their present mineralogy on the map legend (Map 2436, back pocket).

Texturally, these rocks range from true schists, to bimodal granular quartzofeldspathic rocks similar to the original wacke, but most are porphyroblastic with relatively equigranular, weakly foliated biotitic matrices. Even in rocks showing the bimodal grain size distribution, mud-sized particles are uncommon because the fine fraction of the original wacke has recrystallized to form fine sand-sized quartz and feldspar grains and phyllosilicates. A greater degree of recrystallization produces a nearly equigranular texture, almost granoblastic in appearance. The particle size of such rocks is commonly in the range of medium to coarse sand (Wentworth scale).

Schistose and gneissic rocks are uncommon, even near the gradational contacts with the southern migmatitic rocks. The contacts are characterized by numerous thin (0.5 to 3.0 m) sill-like intrusions of massive pegmatoid and granitoid quartz monzonite, sharply interlayered with slabs of granoblastic metasediments. Numerous large rafts of metasediment occur in the granitoid rocks near the contacts.

Porphyroblasts of biotite, almandine, staurolite, andalusite, sillimanite (mostly fibrolite), and cordierite are all common in these meta-wackes. In some rocks, several of these phases occur together giving rise to rather spectacular weathered surfaces. Biotite and garnet generally form rather small (0.5 cm), equant, subhedral grains, but metacrysts of staurolite, andalusite, and sillimanite occur up to 3 to 4 cm in length. The staurolite is subhedral to euhedral in outline in most rocks, but andalusite, sillimanite, and cordierite are typically anhedral, forming ellipsoidal to irregular shaped masses. By way of exception, euhedral chiastolite (variety of andalusite) occurs in outcrops at the extreme southern end of Attwood Lake. The Al_2SiO_5 polymorphs show inverse size gradation, an increase in size toward inferred stratigraphic tops in some units. This gradation was commonly concomitant with a decrease in the grain size and in the number of other metacryst phases.

Bedding in the meta-wacke sequence is indicated either by obvious size, colour, and textural contrasts in the least altered rocks, or by differences in the type and size of porphyroblasts. Beds generally range from 5 cm to 2 m thick and in most outcrops were less than 0.5 m thick. In some cases, especially in the southern part of the area, the relict bedding is at a high angle to the mineral foliation. Other primary sedimentary features are rarely recognizable in these rocks. Some channel scours, graded bedding, and small scale sole marks were seen in a few localities.

The textural features described are revealed by examining thin sections of these rocks. Biotite occurs in all of these rocks. Sericite is found in the matrix of most samples, but is completely absent in some rocks from the southwestern part of the area. Subhedral knots of coarse muscovite up to 1.5 cm long occur in many thin sections. These appear to be pseudomorphs after some pre-existing porphyroblast, probably andalusite or staurolite. In thin sections of the better preserved meta-wackes, some lithic fragments are commonly discernible, but twinned feldspar is uncommon. The exact classification of the original wacke is in most cases impossible, but it appears to have been a lithic subarkosic wacke to a feldspathic lithwacke.

The mineralogy of these meta-wackes is further discussed in the section , "Metamorphism".

Chemical Metasediments

Units of ferruginous chemical metasediments constitute a small, but significant proportion of the metasedimentary sequence, and are also found intercalated with the surrounding metavolcanics in a few localities. In general, these rocks are very poorly exposed. Weak aeromagnetic anomalies associated with them allow some units to be traced for several kilometres along strike.

MASSIVE AND LAYERED FERRUGINOUS CALC-SILICATE ROCKS

Volumetrically, the most important of these chemical metasediments is a coarse-grained ferruginous calc-silicate rock consisting of hornblende and almandine with variable amounts of quartz, actinolite, and magnetite. In the south-central part of Attwood Lake, this rock type forms prominent outcrops along the lakeshore and islands for about two kilometres. The rock is very hard and dark. Although it generally appears quite massive, distinct gneissic banding, which may be related to original layering, is visible in some places. Some of these gneissic layers are siliceous, and may represent meta-chert units. Even in the more massive material, close examination of the outcrops often reveals textural and grain size differences between adjoining layers of essentially the same mineralogy. Pyrrhotite occurs disseminated and in small pods and lenses in these outcrops. Over a short distance across the apparent strike, the garnet-amphibole material is gradational into a very soft, friable, rusty, light grey-green amphibolite rich in graphite. Chemical analyses of these rocks show that they can contain between 15 to 20 percent iron (elemental), see analyses 28, 32, and 33 (Table 2).

Similar rocks consisting essentially of hornblende or hornblende and garnet with variable amounts of quartz occur in the lower part of the clastic metasedimentary sequence west of Hurst and Felsia Lakes, and in the metavolcanic sequence west of Attwood Lake. Like the first occurrence described, these rocks are massive, commonly rusty, and contain disseminated pyrrhotite and-(or) pyrite. These sulphide minerals as well as the variable amounts of magnetite and graphite found in these units, make them moderately strong electromagnetic conductors and bodies of relatively high magnetitic susceptibility.

Thin section examination of these rocks confirmed the relatively simple mineralogy visible in hand specimen. Siderite was also noted in some samples. Cummingtonite-grunerite may occur in the rusty, friable material, but that could not be confirmed petrographically.

LAMINATED MAGNETITE-QUARTZ IRONSTONE AND SIDERITE-QUARTZ IRONSTONE

A second type of ferruginous chemical metasediment, magnetite-quartz ironstone, is much less common in outcrop in this area. Thin units, only a few centimetres wide, intercalated with meta-wackes occur west of Hurst Lake and Felsia Lake. Minor units also occur in the mixed metavolcanic sequence northeast and southwest of Vertente Bay.

Also found in the Vertente Bay-Auger Lake area are relatively thin units of interlayered siderite-quartz ironstone and chert. In some outcrops these occur together with massive hornblende-garnet rock. The individual layers in the carbonate-bearing rocks vary between 2 mm to 2 cm thick, and overall, the units including interlayers of chert and graphitic schist are less than 2 m thick. Typically, the carbonate-rich layers consist of siderite, epidote, calcite, quartz, and magnetite. Calcite and magnetite form moderately strong foliations parallel to the bedding. Other layers are rich in biotite and contain quartz and minor carbonate. These layers may have been derived from original mudstone lami-

TABLE 3 | METAMORPHIC MINERAL ASSEMBLAGES FOUND IN METASEDIMENTS AND METAVOLCANICS OF THE ATTWOOD LAKE AREA; ALL ASSEMBLAGES INCLUDE QUARTZ AND PLAGIOCLASE FELDSPAR.

Metasediments: (in order of decreasing abundance)

Biotite + garnet
Biotite + muscovite ± garnet
Biotite + muscovite + sillimanite ± garnet
Biotite + muscovite + staurolite ± garnet ± andalusite
Biotite + staurolite + sillimanite ± garnet ± andalusite
Biotite + muscovite + sillimanite + cordierite
Biotite + garnet + cordierite
Biotite + muscovite + staurolite + sillimanite + andalusite

Mafic Metavolcanics:

Hornblende + magnetite ± epidote ± garnet ± sericite ± biotite ± sphene

Felsic to Intermediate Metavolcanics

Biotite + muscovite ± epidote ± garnet ± potassic feldspar
Muscovite ± epidote
Biotite + hornblende + epidote ± sericite
Hornblende ± actinolite

nae or fine-grained tuff beds.

The indistinct nature of the weathered surface of the laminated quartz-siderite ironstone-bearing sequences and the small sizes of its units, suggest that these rocks are more abundant than is indicated on the accompanying map (Map 2436, back pocket). These rocks are very commonly found in the vicinity of laminated felsic to intermediate tuffs, and are easily mistaken with them.

Metamorphism

The supracrustal rocks in this area can be classed in terms of metamorphic rank as (cordierite-almandine) medium grade (Winkler 1976). This conclusion is based on several criteria evident from petrographic analysis. Table 3 gives summaries of mineral associations in metasediments and metavolcanics from this area. These criteria are:

1) Staurolite and cordierite occur throughout the meta-wacke sequence.
2) Chlorite is found within the metasediments only as a retrograde phase cross-cutting main metamorphic foliations.
3) Chlorite and actinolite are not present in the mafic metavolcanics.
4) Sillimanite and andalusite are common in many of the metasediments around the southern and central parts of Attwood Lake. In sev-

eral sections studied these minerals occur together in the same rock without obvious inversion relationships.

In terms of absolute pressure and temperature, maximum metamorphic conditions attained in most of this area were in the order of 3.3 kbars and between 550 to 600°C. Local zones of higher metamorphic rank may occur in the southern part of the area, but evidence for this is inconclusive. Muscovite is totally absent from some meta-wackes in the extreme southwestern part of Attwood Lake and in metasedimentary inclusions within the pegmatoid quartz monzonite around the southern end of Weese Lake. There is evidence that at least some of this granitic material was anatectically derived; garnets are abundant in most outcrops, and marked grain size variations occur randomly over short distances.

Mafic Intrusive Rocks

WEESE LAKE ANORTHOSITE

Just west of Weese Lake, a mafic sill, some 600 to 700 m thick, consisting of anorthosite to anorthositic gabbro, intrudes the supracrustal rocks. This sill has been interpreted to extend for at least 25 km to the southwest through Luella and Shabuskwia Lakes (McNamee 1962), but exposure is very poor over much of the intervening area.

Immediately to the east of the sill's sheared contact, there is a thin, poorly exposed sequence of metasediments, 100 to 150 m thick, which parallels the western shore of Weese Lake. These metasediments, which are mostly metawackes and interbedded polymictic pebble conglomerates, appear to pinch out to the north where mafic to intermediate metavolcanics are in contact with the anorthositic body on both sides. Contacts with the supracrustal rocks are sharp, and both metavolcanic and metasedimentary inclusions up to several metres long are common within the sill.

For most of its length within the map-area, the anorthositic rocks on the western side of the sill are probably in contact with gneissic biotite trondhjemite of the Shabuskwia Lake Batholith. Their mutual contact occurs along a swampy depression, and their age relationship was not established with certainty. Minor gabbro and diorite dikes which cut the anorthositic body and which are probably related to it, also intrude the granitoid rocks. This suggests that either the sill is younger than the trondhjemite or their age difference is small. The conformable nature of the body, especially around the northern part of Weese Lake would suggest that it is pre-tectonic, and probably older than the batholith.

In the southwestern corner of the area, the anorthositic rocks are intruded by large masses of pegmatoid quartz monzonite associated with the Southern Pegmatitic Zone (see section on "Felsic to Intermediate Intrusive Rocks"). Between Weese and Luella Lake, which lie to the southwest, the sill is completely obliterated by intrusive phases related to this zone.

The sill is predominantly composed of anorthosite consisting of 90 percent

bytownite, and the remaining 5 to 10 percent is mostly chloritized amphibole and epidote with minor iron-titanium oxides and sphene. The original igneous texture is well preserved. Randomly oriented plagioclase grains in the order of 0.5 to 1.5 cm long, are subhedral and well-twinned, but the feathery chlorite pseudomorphs generally occur in interstitial clots up to 2 cm across. With a decrease in the proportion of plagioclase, the anorthosite grades across strike into gabbroic anorthosite or anorthositic gabbro both of which are common.

Most outcrops are massive, homogeneous, and white to grey weathering. There is no evidence of rhythmic layering indicative of fractional crystallization and settling. The black chloritized amphibole knots typically resist weathering, giving the outcrops a rugged spotted appearance. Small, black, irregularly shaped hornblendite pods, a few centimetres to a few metres long, are found in a few places. The origin of these pods is unclear; they may be inclusions of mafic metavolcanics, intrusive diabase bodies dissected by tectonic movement and deformation, or parts of a broken up metapyroxenite cumulate layer formed within the sill.

Near the eastern contact of the sill, the texture and mineralogy of the anorthositic rocks have been profoundly changed, probably by dynamic metamorphism. These rocks are very soft and typically highly contorted. In some cases they consist of heavily sericitized anhedral plagioclase (50 to 70 percent), stellate bundles of coarse grained tremolite (15-30 percent), and scattered grains of coarse chlorite, hornblende, and biotite in a fine-grained quartzofeldspathic matrix rich in fine-grained epidote and sphene. In other samples, the anorthosite has gone almost completely to amphibole (tremolite-actinolite), and chlorite with small clusters of biotite. Fuchsite is also reported in these rocks (McNamee 1962). Rocks rather similar in appearance to those just described occur in the southwestern corner of the map-area, but they appear to be derived from metasedimentary inclusions within the anorthosite.

Metallic minerals found in the sill include disseminated titaniferous magnetite, pyrrhotite, minor chalcopyrite, and native copper. Known concentrations of chalcopyrite are discussed in the section "Economic Geology".

MINOR METAGABBRO-DIORITE INTRUSIONS

In the map-area, minor mafic intrusions are only common in two localities. These are: 1) in the vicinity of the Weese Lake Sill, where metagabbroic and dioritic dikes and sills cut the anorthositic rocks, the enclosing supracrustal rocks, and the gneissic rocks found to the west; and 2) in the eastern part of the map-area where dikes intrude trondhjemitic rocks of the Hurst Lake Batholith.

The minor intrusions associated with the Weese Lake Sill generally consist of fine- to medium-grained foliated to gneissic amphibolite. In thin section, these rocks are revealed to consist essentially of plagioclase, hornblende, quartz and iron-titanium oxides. In the anorthositic body itself and in the gneissic trondhjemite to the west, sills and dikes up to 15 m wide are very common. Most appear to be irregular in shape, but their contacts are sharp.

In the supracrustal sequence to the east of the anorthosite body, however, all of the minor mafic intrusions appear to be regular and conformable. A mas-

sive metagabbro sill appears to separate metasediments from metavolcanics around the northern part of the main body of the Weese Lake Anorthosite Sill.

The gabbroic intrusions in the eastern part of the area generally have far better preserved texture and mineralogy than those rocks just discussed. Most of those intrusions are quite small and are not shown individually on the accompanying map (Map 2436, back pocket). Others are over 100 m wide, but even those are not traceable in the field for more than a few hundred metres. The contacts, where exposed are sharp, and generally cross-cut the foliations in the surrounding rocks.

Sub-ophitic texture is well preserved in thin sections examined. Unaltered augite grains up to 3 mm across enclose labradorite laths, which in some cases are lightly to heavily saussuritized. Quartz occurs interstitially with plagioclase, iron-titanium oxides, and alteration products such as uralite, chlorite, and epidote between the large pyroxene grains. Streaks of quartzofeldspathic material may be remnants of plagioclase phenocrysts in some dikes. Most of these rocks appear to be quartz gabbros.

The dikes are quite massive except for joint patterns which are generally well developed parallel and normal to the contacts. Chilled margins are quite well developed in the larger bodies.

The absolute age(s) of these cross-cutting, relatively fresh mafic intrusive rocks is not known. Although no age determinations have been made on rocks from the local dikes, these dikes are similar in many aspects to those dikes in the Miminiska Lake area which have been dated as Middle Precambrian (Wanless *et al.* 1966, p.74) by whole-rock K-Ar methods.

LAMPROPHYRE

One lamprophyre dike at least 3 m wide in places, was found in the southernmost bay of Attwood Lake. The rock is a soft, massive dark green weathering biotite-hornblende lamprophyre in which subhedral phenocrysts of biotite and hornblende as well as small metacrysts of almandine occur scattered in a very fine grained hornblende-rich matrix. On the small island exposure indicated on the accompanying map, (Map 2436, back pocket), the lamprophyre is dissected by numerous quartz veins and stringers up to 0.5 m wide.

Felsic to Intermediate Intrusive Rocks

The felsic to intermediate intrusive rocks which nearly surround the supracrustal sequence in this area can be grouped, on the basis of location, composition and origin, into four subdivisions. Three of the four subdivisions are believed to represent discrete intrusions. The fourth group of rocks forms part of a paragneissic migmatite zone designated the "Southern Pegmatitic Zone" in this report, which extends far to the south of the current map-area.

HURST LAKE BATHOLITH

The precise shape and dimensions of this intrusion are not known. Most of the body lies east and north of the current map-area, where it is probably bounded by migmatitic rocks and other plutonic masses. Only reconnaissance mapping has been done in that part of the region (Thurston and Carter 1970).

The contact with the supracrustal rocks around Hurst and Felsia Lakes was fairly well defined by the field party. The contact appears to be highly irregular in shape. Apophyses of the granitoid batholith extend hundreds of metres into the metavolcanic sequence to the west, and porphyritic granodiorite forms *lit-par-lit* injections into the metavolcanics for a similar distance. Numerous oriented inclusions of mafic flow rocks and felsic to intermediate flow and pyroclastic rocks a few metres to several hundred metres across occur. These inclusions are within that part of the batholith in the map-area that is as far as 2 km or more from the general contact which follows the western sides of Hurst and Felsia Lakes.

Within the map-area, this batholith consists of biotite trondhjemite, but locally, especially near the contact with the supracrustal rocks and in the vicinity of large inclusions, the composition of the granitoid rocks is highly variable due to hybridization. Near the contacts with mafic metavolcanics, the hornblende content of the rock increases forming quartz diorite. In other places around felsic metavolcanic inclusions, the rocks appear to be quartz-rich granodiorite. Commonly, the rocks are porphyritic with phenocrysts of plagioclase forming up to 5 percent of the rock. The ferromagnesian mineral content is generally low, but a distinct mineral foliation is observable in most outcrops. Good granitic texture (hypidiomorphic-granular) is seen on some exposures, but most exhibit saccharoidal textures indicative of recrystallization.

In thin section, these rocks are seen to consist of polygonized masses of quartz intergrown with rounded to subhedral, well-twinned plagioclase grains, that are commonly saussuritized, and are separated by small amounts of fine-grained quartzofeldspathic "mortar" and fine-grained green biotite and chlorite which typically occur in clots. Plagioclase phenocrysts (oligoclase) up to 1.5 cm across, are euhedral, and are commonly distinctly zoned. Rocks exhibiting seriate textures with respect to plagioclase also appear to be common.

VICK LAKE BATHOLITH

The contacts of this intrusion, like those of the Hurst Lake Batholith, are little known outside the current map-area. To the north, the Vick Lake Batholith is covered by thick morainic deposits, and its contacts with the Miminiska Lake metavolcanics are completely obscured. The intrusion probably extends to the west for at least 35 to 40 km where it is in contact with mafic metavolcanics near the Misehkow River. Its inferred southern contact with rocks of the Shabuskwia Lake Batholith remains tentative. The subdivision of the large area of granitoid rocks west of the map-area into the Vick and Shabuskwia Lake Batholiths is based only on weak aeromagnetic contrasts between the two batholiths, and on differences in the common rock types seen in the current

map-area. To some extent, the latter may be misleading because the rocks mapped on the western side of the Weese Lake Anorthosite Sill can be considered as only contact phases of the Shabuskwia Lake Batholith.

North of Weese Lake and west of Auger Lake, contacts between the Vick Lake Batholith and the Attwood Lake metavolcanics are well exposed. Over a zone about 200 to 300 m wide the contact is characterized by the following: *lit-par-lit* intrusion of thin sills into the metavolcanics, intrusion breccias in which mixtures of angular metavolcanic and metasedimentary fragments up to 2 m long occur in a porphyritic granodiorite; and true migmatite, consisting of schistose to granoblastic remnant units of mafic and intermediate to felsic metavolcanics and biotitic metasediments dissected by numerous gneissic injections. Beyond this contact zone, recognizable xenoliths are relatively uncommon in the batholith, but gneissic patches which may represent granitized supracrustal blocks are quite common.

Overall, the batholith appears to be rather heterogeneous. The dominant phases are foliated leucocratic porphyritic trondhjemite to granodiorite with equant plagioclase phenocrysts. Biotite and hornblende are common, occurring in all relative proportions, but biotite is generally predominant. On individual outcrops, the rocks vary markedly in their quartz and ferromagnesian mineral contents, and in their degree of mineral foliation and gneissosity, but only rarely are contacts between phases found.

Petrographic examination shows that oligoclase forms 50 to 70 percent of these rocks. The plagioclase is generally weakly saussuritized, equant, and subhedral. Quartz which constitutes 15 to 30 percent by volume is anhedral and interstitial to the much larger plagioclase grains. Anhedral microcline (2 to 10 percent) is similar in size and form to quartz. Coarse flakes of biotite and hornblende prisms occur scattered throughout most thin sections examined. Sphene, epidote, zircon, sericite, and iron-titanium oxides make up the rest of the rock.

SHABUSKWIA LAKE BATHOLITH

West of Weese Lake, the anorthositic sill is bounded by rocks of the Shabuskwia Lake Batholith. The rocks exposed within the current map-area are gneissic porphyritic biotite granodiorite intruded in places by more massive quartz monzonite. Xenoliths of amphibolite occur in some outcrops close to the sill itself.

In thin section, the gneissic rocks from this intrusion are characterized by sericitized plagioclase phenocrysts, sericitized plagioclase in the groundmass, and by subcontinuous lensoidal aggregates of biotite which give rise to gneissic layering.

SOUTHERN PEGMATITIC ZONE

In the southwestern and south-central parts of the map-area, the metavolcanics, metasediments, and the Weese Lake Sill are cut by numerous intru-

sions consisting of white, muscovite-bearing, pegmatitic, biotite quartz monzonite. These intrusions vary widely in dimension and orientation. Many are simple dikes or sill like bodies less than 1 m wide, but there are many other very large irregularly shaped masses. The extreme southwestern corner of the map-area is underlain largely by medium- to coarse-grained granitoid rocks of similar composition, which include abundant metavolcanic and metasedimentary xenoliths of varying dimensions in various stages of assimilation.

These pegmatoid to granitoid quartz monzonitic rocks are generally massive and show little indication of mineral foliation. Graphic intergrowths of feldspar and quartz are common. Gradational changes in grain size occur everywhere in a random fashion. Sharp contacts are few. The coarser phases generally weather pinker, and contain more muscovite, which forms "books" up to 2 cm across, than the rest of the rock.

The common occurrence of garnet in these rocks, and the predominance of muscovite over biotite in many phases, as well as the irregular grain size variation, suggest that these rocks have been derived anatectically from metasediments in the projected continuation of the Attwood Lake supracrustal sequence south of the map-area.

Phanerozoic

CENOZOIC

Quaternary

PLEISTOCENE AND RECENT

Bouldery and sandy till cover most of the map-area. According to the limited diamond-drill hole data available, the depth to bedrock is generally in the order of 2 to 8 m. The thickest and most complete cover occurs in the southeastern part of the area where depth to bedrock may be over 20 m.

The only prominent Pleistocene features in the map-area are two esker systems. One continuous esker diagonally transects the area from Auger Lake to Weese Lake. This system for most of its length consists of a broad relatively low plain, 100 to 300 m wide, averaging 10 to 15 m in height. However, in the Weese Lake area, it takes on the classical narrow, steep-sided, sinuous form. In places just north of the east end of Weese Lake, the centre of the ridge is approximately 30 m above the surrounding apron of formerly superglacial material which is pocked by several large kettle-like depressions.

The second major esker system extends in an east-west direction across the southeastern corner of the map-area. The north-flowing Witchwood River has been forced to make a sharp "detour" of almost 2 km from its preferred course to circumvent the major part of this esker, and crosses the barrier at its narrowest point where the crest of the steep-sided ridge is about 20 to 25 m above the riv-

er. A major branch of this esker system, notable for its sharp outline and steep sides, extends to the south out of the map-area midway between Attwood Lake and the Witchwood River.

The last glacial movement in this region, indicated by striations on hard igneous outcrops and by the orientation of glacially moulded ridges and depressions in the northwestern and southeastern parts of the area, is consistently toward azimuth 230° to 235°.

STRUCTURAL GEOLOGY

Regional Setting

The rocks of the Attwood Lake area form part of the Uchi Belt (Ayres *et al.* 1970) which is a lithologic and structural subprovince of the Superior Tectonic Province consisting predominantly of metavolcanics and metasediments with east to east-northeast-trending structural elements. The local supracrustal sequence is a southerly appendage to the main segment of the Uchi Belt which lies 10 to 20 km to the north, and diverges from the general trend of the subprovince in that structural elements are oriented north-south to northeast-southwest.

Near the southern boundary of the map-area, the Uchi Belt is in contact with the English River Belt, a second subprovince which is dominated by plutonic masses and metasedimentary migmatitic rocks. This subprovince boundary appears to be gradational; the supracrustal sequence is traceable across the inferred boundary, and intrusive rocks of the English River Belt intrude the supracrustal rocks well north of the boundary. In the map-area at least, there is no indication of major structural dislocations such as faults between the subprovinces as have been documented along the boundary further west.

Major Structures

The structural complexity of this area is difficult to unravel because of poor exposure and lack of critical facing data. Nevertheless, a number of large scale features are evident.

MAJOR FOLDS

The distinctive rectangular outline of the area underlain by supracrustal rocks around Attwood Lake is the product of an interference pattern between a nearly isoclinal northeast-trending primary fold, the axis of which parallels Attwood Lake, and a major northwest-trending cross-fold which extends from the northwestern corner of Weese Lake through the southern part of Attwood

Lake just north of the central peninsula. The first fold is interpreted to be a syncline, the axis of which, based on the orientation of minor fold axes, appears to plunge moderately southwestward in the north, and appears to undulate between subhorizontal to northeast-plunging in the central and southern parts of the area. Evidence for the interpretation of this fold as a syncline is, however, not certain. Pillow tops to the west of Attwood Lake are generally east-facing, indicating that the fold's central core of metasediments is younger than the surrounding metavolcanics. Many pillow tops and some features within bedded pyroclastic rocks and metasediments around the nose of the fold in the northeastern part of the map-area, however, do not appear to support the existence of a syncline. This inconsistency may be more apparent than real when the major faulting and the effects of cross-folding in this area are taken into account.

Stratigraphically, the most reasonable interpretation is that mafic metavolcanics are overlain by a mixed sequence of mafic and felsic metavolcanics and chemical metasediments. These are in turn overlain by conglomeratic rocks rich in metavolcanic detritus that gradually pass upward into finer wacke-type metasediments.

The major cross-fold already mentioned is interpreted to be a southeast-plunging syncline, but again the evidence in terms of minor structures, and facing determinations is limited.

Other isoclinal folds subparallel to the Attwood Lake Syncline may occur within the metasediments in the southern part of the area and within the metavolcanic sequence between Auger and Weese Lakes, but these are only suspected from apparent repetitions in local stratigraphy.

MAJOR FAULTS AND LINEAMENTS

The only part of the map-area in which major faults could be discerned was around the north-central section of Attwood Lake where reasonably good exposure prevails. These faults are inferred where obvious stratigraphic offsets occur that are congruent with prominent lineaments visible on vertical air photographs or with aeromagnetic dislocations. In only a few locations was direct evidence for these faults recognized in outcrop. The only common indication of a fault's presence was the moderately strong deflection of foliation in the immediate vicinity of the faults.

The most prominent set of faults is the northwest-trending set which intersects the main Attwood Lake fold at approximately right angles. The horizontal component of movement along these zones appears to be in the order of several hundred metres, but nothing is known of the total amount of slip. A second set of important faults intersects the first at approximately right angles, subparallel to the main fold axis. Again, there is very little direct field evidence for these faults. The strike length of these faults is unknown and may be limited.

Faults shown in the vicinity of Auger Lake are inferred from major lineaments which extend for several kilometres to the north of the map-area. Considerable shearing was noted in outcrops along these faults, and major lithologic contacts were found across them.

Lineaments obvious on vertical air photographs are most numerous in the

northeastern and northwestern corners of the area, in terrain underlain by granitoid rocks. In the northeastern part of the area sets of lineaments, probably following joints, form a conjugate pattern consisting of three distinct sets intersecting at roughly 60°. In the northwest, two prominent sets are recognized. No appreciable offsets appear to be associated with these features.

Many lineaments occur parallel and subparallel to the northwest-trending fault set around northern Attwood Lake. Most of these have not been shown on the accompanying map to avoid confusion (Map 2436, back pocket).

Minor Structures

FOLIATION, SCHISTOSITY, AND GNEISSOSITY

Foliation produced by the parallellism of flattened tephra, pillows, amygdules, pebbles, boulders, etc., is a very common feature. In nearly all cases this flattening is believed to be due to or at least greatly enhanced by, tectonic deformation. Mineral foliation is exhibited in phaneritic rock types to a highly variable degree. Truly schistose rocks are far less common than rocks with moderately strong mineral foliations. Generally, both types of foliation are subparallel to lithologic contacts, but considerable angular discrepancies were noted between bedding and mineral foliation in some places in the southern part of the area.

Secondary foliation produced by crenulation of pre-existing mineral foliation is common in the phyllitic and schistose metasediments in the central part of the area. This crenulation "cleavage" may be much more prominent than the pre-existing planar features. It is commonly characterized by small fractures and kinks from a few millimetres to a few centimetres apart. The trend of these features is generally parallel to the northwest-trending fault set described in the section "Major Faults and Lineaments".

Gneissosity is developed in: 1) many of the mafic intrusive rocks where the layering is generally subparallel to the contacts; and 2) in the contact phases of the batholiths to the north, east, and west of the supracrustal rocks.

MINOR FOLDS

Minor folds, from a few centimetres to 25 m in amplitude, are numerous in meta-wacke and bedded pyroclastic rocks around the nose and along the axial trace of the main Attwood Lake Syncline. Most of these appear to be subsidiary folds with axes subparallel to the major structure, except near the nose where wide variations in axial trend are evident. As noted previously, plunges of the minor structures appear to vary markedly along the axial trace of the major fold, presumably due to the effects of cross-folding.

Minor folding is also common in pyroclastic rocks near the nose of the major cross-fold north of the main body of Weese Lake. Chevron folds, generally

less than 1 m in amplitude have axial traces subparallel to that of the cross-fold and plunge southeastward at approximately 65°.

LINEATIONS

Linear structural elements formed by elongated pillows, sedimentary clasts, amygdules, etc., are fairly prominent in the vicinity of the major fold's axis. Clasts in conglomerates east of Attwood Lake near the nose of the major fold have developed particularly strong lineations. Mineral lineation was not commonly noted except in these conglomerates, east of Attwood Lake, where metamorphic minerals such as garnet and staurolite were commonly found aligned with the axes of minor folds.

JOINTING

Consistent, pervasive joints were most commonly observed in the minor mafic intrusions. These joints are parallel and normal to contacts. Jointing is also prominent in the granitoid rocks in the northeastern part of the area.

ECONOMIC GEOLOGY

Little exploration work has been reported from this area until recently. The remote location, poor access, limited exposure, and lack of geological information has not made this part of the Uchi Belt attractive for exploration.

Despite intermittent prospecting for gold from the late 1920s to the time field work was completed, there have been no occurrences found in the map-area. Most of the exploration for base metals has taken the form of reconnaissance airborne geophysical surveys followed up by ground geophysics and a limited amount of diamond drilling. So far, this approach has proven to be largely unsuccessful.

The full history of mineral exploration in this area has been considered earlier in this report (see section on "History of Mineral Exploration"). A summary of exploration work reported for assessment credit to the Ontario Ministry of Natural Resources is given in Table 4.

Types of Mineral Occurrences

Base-metal sulphide mineralization found so far within the map-area can be placed into three categories which are discussed separately below.

TABLE 4 | INFORMATION ON FILE WITH ASSESSMENT FILES RESEARCH OFFICE, ONTARIO GEOLOGICAL SURVEY, TORONTO, AND/OR REGIONAL GEOLOGISTS FILES ONTARIO MINISTRY OF NATURAL RESOURCES, THUNDER BAY, AS OF DECEMBER 31, 1976.

Name of File	Area	Property Reference Number	Assessment Office File Number	Type of Work	Date of Work
M.J. Boylen Engineering Offices	Hurst and Felsia Lakes Area	1	63-1127	A (M + EM) G (M + EM) G.S.	1961
Canadian Onex Mines Limited	Hurst and Felsia Lakes + Attwood Lake Areas		2-129	A (M + EM)	1970
Imperial Oil Enterprises Limited	Hurst and Felsia Lakes + Attwood Lake + South of Keezhikuns Creek Areas	3	2-970	A (M + EM)	1972
New Jersey Zinc Exploration Company (Canada) Limited	South of Keezhikuns Creek + Attwood Lake Areas	5	63-1175	G.S.P.	1962

Abbreviations: A - Airborne
G - Ground
G.S. - Geological Survey
EM - Electromagnetic Survey
M - Magnetometer Survey
P - Prospecting

MINERALIZATION ASSOCIATED WITH FERRUGINOUS CHEMICAL METASEDIMENTS

Occurrences of pyrite, pyrrhotite, arsenopyrite, and minor chalcopyrite were found in several places along the prominent unit of chemical metasediments which bisects the south-central part of Attwood Lake, and in other units west of the north-central part of the lake. Similar rock types bearing iron sulphides have been intersected by diamond-drill holes between Attwood and Felsia Lakes. These units commonly give rise to linear magnetic and electromagnetic anomalies.

The mineralization generally occurs as small scattered lenticular or irregular pods 0.5 to 10 cm long aligned subparallel to the external foliation. Either pyrite or pyrrhotite predominate in any one occurrence, pyrrhotite is the most common sulphide. Disseminated euhedral grains of arsenopyrite as much as 1 cm in length are also common in some places, notably along the ferruginous calc-silicate zone which parallels the shore of south-central Attwood Lake where the arsenopyrite generally occurs with the other sulphide minerals. The total sulphide mineral content found in some of these occurrences by the field party was as high as 20 percent, but over 60 percent combined sulphide minerals have been reported in diamond-drill logs over core lengths of 1 to 5 m.

Occurrences found so far are commonly closely associated with zones of graphite-rich gossan up to 10 cm thick. The sulphide-bearing zones appear to be stratiform, and probably represent beds or groups of beds.

Chalcopyrite is only a minor component in these occurrences. Small blebs of this mineral as well as malachite were found in pyrrhotite pods in the chemical metasedimentary unit which bisects southern Attwood Lake. Analysed samples of mineralized amphibole-garnet rock from these occurrences indicated low copper values (0.05 percent) and only traces of gold. Small amounts of sphalerite were reported in logs of diamond-drill holes put down by Hudson Bay Exploration and Development Company Limited which intersected similar units just east of the southeastern bay of Attwood Lake.

In the region north of Attwood Lake between Miminiska and Frond Lakes, chemical metasediments similar to those described above are associated with gold and sulphide-bearing quartz veins (Wallace 1978a and b). However, these have not been found around Attwood Lake.

MINERALIZATION ASSOCIATED WITH METAVOLCANICS

Iron sulphide minerals, mostly pyrite, typically occur in amounts up to 5 percent by volume and are disseminated in the intermediate and mafic metavolcanics in the map-area. The sulphide occurs finely disseminated throughout these rocks, or is restricted to the fine matrix of pyroclastic rocks. Sulphide stringers and podiform masses are uncommon.

Small flecks of chalcopyrite were noted in several scattered localities in intermediate to felsic lapillistone in the Vertente Bay area and east of Weese Lake, but only traces of copper were reported in chemical analyses of these rocks.

MINERALIZATION ASSOCIATED WITH THE WEESE LAKE ANORTHOSITE

Mineralization in and around the Weese Lake Anorthosite Intrusion occurs in two forms. The most significant occurrences consist of sparsely disseminated chalcopyrite and pyrrhotite within the anorthosite itself. Reported total sulphide content is only in the order of 1 to 2 percent overall, but erratic lenses, only a few metres in length, containing considerable sulphide concentrations, mostly pyrrhotite, are known in several places (McNamee 1962). A relatively heavily mineralized block of float of this material was reported to have assayed 0.63 percent copper (McNamee 1962).

Chalcopyrite and pyrite also occurs in shear zones and associated quartz veins which cut the anorthosite and younger gabbro dikes along the eastern side of the main intrusion. The chalcopyrite content is generally erratic, varying from trace amounts to over 30 percent (McNamee 1962). The quartz vein and shear zone systems, which are generally north- to northwest-trending, are small volumetrically. The largest system is traceable for only about 100 m and has a width of less than 2 m. The known occurrences do not approach economic significance.

Description of Properties

Several small scattered groups of mining claims were held within the map-area during the current survey. The locations of these claim groups, all of which were held by New Jersey Zinc Exploration Company (Canada) Limited, are shown approximately on the accompanying map (Map 2436, back pocket).

The descriptions below are listed alphabetically under the following headings:

(1) For properties in good standing as of December 31, 1976, by the full name of the company or individual under whose name the claims are registered;

(2) For known mineral deposits on ground no longer held as of December 31, 1976, by a local geographic name or an abbreviated company name;

(3) In the case of an area of notable exploration activity where no mineralization was found, by the name of the last company or individual to have done major work followed by the date of that work in brackets.

Historical details contained in these descriptions are for the most part taken from: company reports on file with the Assessment Files Research Library, Ontario Geological Survey, Toronto; reports and records of the Ontario Geological Survey; from information made available by the companies and individuals concerned.

Location numbers in parentheses after the name of each property correspond to designated sites on the accompanying map (Map 2436, back pocket).

HUDSON BAY EXPLORATION AND DEVELOPMENT COMPANY LIMITED [1971] (1)

In 1971, this company put down nine diamond-drill holes totalling 1196.5 m in length in separate localities scattered across the southern part of the map-area. These holes were drilled to investigate geophysical anomalies which appeared to be associated with major units of chemical metasediments such as the prominent unit which extends longitudinally through southern Attwood Lake, and the major unit between Attwood and Felsia Lakes. Several of the diamond-drill holes encountered wide intersections of massive and layered garnet-amphibole rock which contained zones of massive pyrrhotite and pyrite. The most notable of these intersections occurred on the peninsula on the east side of Attwood Lake where 75 percent pyrrhotite was reported over a length of 2 m at a vertical depth of 40 m. On the peninsula on the western side of Attwood Lake, another diamond-drill hole intersected 20 to 25 percent pyrrhotite over a length of 6 m at a vertical depth of 60 m. No mineralization other than pyrrhotite and pyrite was mentioned in the diamond drill logs.

IMPERIAL OIL ENTERPRISES LIMITED [1972] (2)

This company, in 1972, conducted ground magnetic and vertical-loop electromagnetic surveys over eight small grid systems in the map-area. This work followed up earlier airborne geophysical reconnaissance. Later, exploratory diamond drilling was done over anomalies north of Vertente Bay and between Vertente Bay and the eastern arm of Weese Lake. Only a few of these diamond-drill holes were located in the field. The locations of other diamond-drill holes are not known to the author.

M.J. BOYLEN ENGINEERING OFFICES [1961] (3)

In 1961, M.J. Boylen Engineering Offices did considerable exploration work on a group of 36 claims which extended into the northeastern corner of the current map-area around Auger Lake. The area is mainly underlain by a mixed mafic to felsic metavolcanic sequence.

The map-area was included in a combined airborne magnetometer and electromagnetic reconnaissance survey flown in 1960. The following spring, ground magnetic and vertical-loop electromagnetic surveys were conducted over geophysical anomalies outlined by the airborne work. Trenching and geological mapping as well as a limited amount of diamond drilling to the north of the map-area were also carried out at that time. Zones of weak disseminated sulphide mineralization believed to be the cause of the geophysical anomalies were found in some metavolcanic units, but no economically significant discoveries were made (Baldwin 1961). The claims were subsequently allowed to lapse.

CANADIAN ONEX MINES LIMITED [1970]

In February 1970, most of the current map-area was covered by a combined airborne magnetometer and electromagnetic survey flown for Canadian Onex Mines Limited. A number of widely scattered conductors associated with magnetic high responses was found (Fountain 1970) and claims were staked over several of them in the summer of 1970. No further follow-up work has been reported.

NEW JERSEY ZINC EXPLORATION COMPANY (CANADA) LIMITED (4)

In 1976, this company held 32 claims in nine small separate claim groups, around the northern part of Attwood Lake. These had been staked on the basis of airborne geophysical results. Geological mapping and prospecting were done around these blocks as part of a larger program of mapping, geophysical surveying, and diamond drilling centred about 4 km northeast of Auger Lake.

Except for one group of four claims on the Vertente Bay peninsular, the company's ground was allowed to lapse in 1977.

WEESE LAKE OCCURRENCE (5)

A number of small sulphide mineral showings known to contain appreciable chalcopyrite occur within and around the Weese Lake Anorthosite.

History

The ground west of Weese Lake, parts of the lake itself, and an area extending to the southwest toward Luella Lake, were first staked in 1961-62 by New Jersey Zinc Exploration Company (Canada) Limited. A total of 56 claims were involved within the map-area. In 1962, the company did considerable exploration work on the claim group including ground magnetometer and electromagnetic surveys, geological mapping, trenching, and prospecting. This work was followed-up by diamond drilling over geophysical anomalies, most of which appeared to be linear north-south-trending zones in the metavolcanics east of the anorthositic sill, and in the vicinity of known sulphide occurrences within the sill. The known occurrences and diamond drill holes in this area are shown in Figure 4.

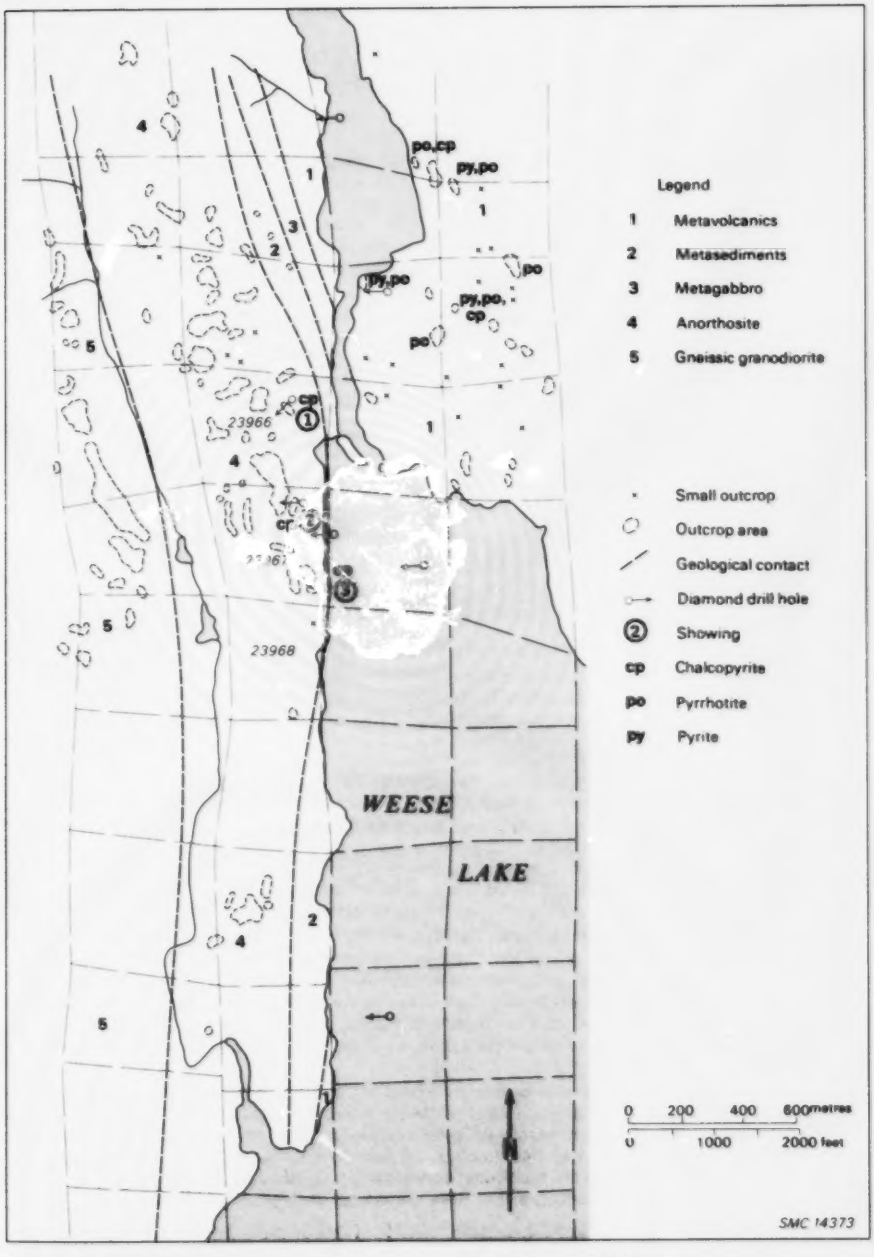

Figure 4–Sketch map of the Weese Lake Occurrence (after McNamee 1962).

Mineralization

The following account of mineralization on this old property is given by McNamee (1962) in a report for New Jersey Zinc Exploration Company (Canada) Limited:

Three, and possibly five occurrences, carrying quantities of up to 40 percent chalcopyrite have been discovered along the east flank of the bytownite anorthosite on claims 23966, 23967, and 23968. They are not ore: they are too narrow, too dispersed, and too erratically mineralized. Taken together, however, they form a mineralized zone 2300 feet long that contains almost all of the economic sulfide encountered on the claim block and constitute with disseminated chalcopyrite in the anorthosite a low grade copper zone whose overall tenor is presently well below the economic limit.

The first of these zones is the "Cryderman Showing", discovered by prospectors Jim Cryderman and Tom McNaughton shortly before New Jersey Zinc [Exploration Company (Canada) Limited] moved into the area. It is essentially a quartz filled shear, striking 160° to 138° across anorthosite and gabbro (offsetting the latter) carrying 4 percent to 6 percent chalcopyrite over 2 to 3¼ foot widths. Exposures outcrop along strike for 100 feet, then pass, on both ends, into gravel. Assays for gold and silver made in 1961 returned trace and 0.7502 respectively.

Chalcopyrite accompanied by "arrow-head" shaped clusters of pyrite crystals fills shearing planes in the quartz and replaces sheared anorthosite and gabbro outward from the vein. Unsheared rocks are not mineralized. The amount of quartz diminishes rapidly to the southwest, tailing out into ½ inch wide stringers, and increase apparently to the northwest, where the last exposure in a shallow pit shows nearly 3 feet of quartz.

On the northeast side of the zone small gabbro outcrops and rubble blocks contain considerable quartz and a little chalcopyrite. Scattered chalcopyrite-bearing float, obviously derived from the showing occurs in the immediate vicinity.

Fairly extensive drift cover, particularly to the southeast prevents any expansion of the mineralized area beyond its present confines.

The second zone is one of chalcopyrite bearing anorthosite rubble and quartz float.

Drift and rubble cover obscures the orientation and configuration of this zone necessitating the use of float and a single outcrop for geological information. From these, it appears that the mineralization - chalcopyrite - is confined to a zone of slight fracturing and shearing, in the anorthosite crossed by a few quartz veins probably 6 inches to 2 feet in width, the whole possibly oriented along the regional strike, i.e. 165° - 180°. The one mineralized outcrop has a 10 foot x 10 foot "burnt" patch of sparsely disseminated chalcopyrite and a mildly sheared spot 1' x 5' carrying about 10 percent chalcopyrite. Most of the chalcopyrite-bearing rubble is also slightly sheared - enough to shatter and rudely align the feldspars, but insufficient to produce schistosity or recrystallization. Chalcopyrite percentages vary from 0.5 percent to 8 percent with an average content of 2 percent to 3 percent. Within the quartz float this percentage is less constant, ranging from practically nothing to the almost total sulfide replacement of the massive 30 lb. chalcopyrite boulder found here by the writer in 1961 (assay 10.80 percent Cu., 0.09 oz. Au., 1.55 oz. silver).

Similar mineralization - the third zone - is repeated further south on claims 23967 and 23968, again through float and rubble rather than outcrop. One small outcrop on the control line shows a 2 foot width of quartz vein and slightly sheared anorthosite, striking 120° erratically mineralized with chalcopyrite. Quartz and anorthosite float in the immediate vicinity, probably derivatives of the outcropping zone, carry 2 percent to 30 percent chalcopyrite and some native copper. A large outcrop also contains a quartz vein, 6 inches wide, striking 165°, carrying 2 percent to 6 percent chalcopyrite.

More quartz-sheared anorthosite-chalcopyrite float some of which is tourmaline bearing (black radiating clusters in the quartz) occur intermittently along the rubble ridge south of the small quartz-chalcopyrite outcrop. Most, maybe all of this comes from the outcropping zone - however 60 feet and 360 feet south of that zone the mineralized float is so arranged, approximating the 120° strike, to suggest that it represents additional non-outcropping chalcopyrite bearing veins. This is particularly true of tourmaline-bearing float from the second (360 feet south) occurrence.

In another section of that report, McNamee (1962) described disseminated sulphide mineralization in the anorthositic sill as follows:

> Apart from its association with the quartz-chalcopyrite veins, sparsely disseminated chalcopyrite and pyrrhotite (sometimes nickeliferous-dimethylglyoxime test) also form small erratic "burnt" patches through the anorthosite. These usually attain dimensions only in the 10's of feet and never contain more than 1 percent - 2 percent sulfides. A selected sample from a large float block of such mineralization found just south of line 56 gave 0.63 percent copper and this is considerably above the average metal content of these zones. The quantity of nickel, judged from the percentage of pyrrhotite within the zone is insignificant.

SUGGESTIONS FOR FUTURE EXPLORATION

Most of the recent exploration for base-metal sulphide deposits in this area has been in the mixed metavolcanic sequences north and west of Attwood Lake. This is undoubtedly due to the fact that considerable felsic to intermediate pyroclastic material is well exposed there, and that several prominent geophysical anomalies appear to be associated with these metavolcanics. There are, however, two zones within the map-area which are underlain largely by felsic to intermediate metavolcanics and which do not appear to have been examined for metallic deposits. One is a lens of metavolcanics on the southeastern side of Attwood Lake. It consists of felsic tuff and lapillistone, but nothing is really known of its true extent or internal stratigraphy. The second unexplored part of the area which may warrant examination is the broad contact zone between the Hurst Lake Batholith and the metavolcanics to the west. Large inclusions of felsic, intermediate, and mafic metavolcanics, including a high proportion of pyroclastic rocks occur within the batholith west of Hurst Lake. These areas should be prospected for base-metal sulphide occurrences. Quartz veins within the inclusions and near their contacts should be examined for gold.

A number of small sulphide occurrences near the northern arm of Weese Lake give some encouragement for further prospecting in the mixed metavolcanic sequence between Weese Lake and Vertente Bay.

Many gold occurrences in the Miminiska Lake area, which lies to the north of Attwood Lake, are associated with arsenopyrite-bearing amphibole-garnet-biotite rocks similar to some chemical metasediments in this area. Quartz veins found in and around such units should be assayed for gold.

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